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The Outlook of Electric Vehicles in Finland and Europe – Understanding the Challenges in Growth of Electrified Mobility

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Electric vehicles play a key role in the future of transportation. The future of passenger transport will be more electric and the transition from ICE vehicles to electric ones is going to happen gradually over the next decades. Progress has been made in the charging network, in the battery capacity, and the overall development of electric vehicles is becoming faster. By many, electric vehicles are expected to be the choice of driving in the future. But the growth of electric vehicles requires the right conditions to succeed: price must be competitive enough, charging network sufficient enough and the driving range long enough. However, in Finland many of these conditions are still not at the level as people want and therefore, they are not buying electric vehicles as much and the sales growth is very slow.

The battery industry is expanding fast and many European car manufacturers are investing in electric vehicle technologies, including batteries. This creates pressure to find new sources of raw materials and make the current supply chain much more efficient. Key materials like cobalt and lithium are very concentrated in only a few locations around the globe, creating risk of supply shortages and bottlenecks. Recycling of battery materials is still in the early phase of development in terms of efficiency and needs to be more advanced to fully take advantage of the existing battery materials. Establishing European’s own battery manufacturing production and supply chain of materials for EVs will be challenging but has great potential for future manufacturing.

It is estimated that there would be a drastic increase of electric vehicles in Finland by 2030, but as this thesis suggests, with the current rate of development it will take more time than expected. Increasing interest towards electric vehicles keep growing but the automotive industry need to keep developing electric vehicles technology and the infrastructure around them.

This thesis focuses to explain more about the growth scenario of electric vehicles and identify the issues related to that. Helping to understand the reasons why growth of electric vehicles is challenging in Finland and even in Europe. The findings of this paper can be useful for people considering buying and EV or need information about them, offers information and an outlook of EVs for policy makers and to other decision makers regarding electric vehicles infrastructure.

**Keywords**

Electric vehicle, EV, battery materials, ICE cars, CO2 emissions, zero emission, electric mobility.
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### Key terms and abbreviations

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<th>Abbreviation</th>
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<tr>
<td>EV</td>
<td>Electric Vehicle.</td>
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<td>BEV</td>
<td>Battery Electric Vehicle.</td>
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<td>PHEV</td>
<td>Plug-in Hybrid Electric Vehicle.</td>
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<td>HEV</td>
<td>Hybrid Electric Vehicle.</td>
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<td>ICE</td>
<td>Internal Combustion Engine.</td>
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<td>DC</td>
<td>Direct Current.</td>
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<td>AC</td>
<td>Alternating Current.</td>
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<td>RFID</td>
<td>Radio Frequency Identification.</td>
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**Regenerative Braking**  
A process where the electric motor helps to slow down the vehicle and create electricity by converting the heat energy normally used by the breaks to charge the battery.

**KWh**  
Battery capacity is measured in kilo Watt hours which indicates how far the car can be driven and how fast the battery can be charged.
1 Introduction

Conventional petrol and diesel cars have been dominating the passenger cars markets around the world for the last century, but in recent years we have seen increasing amount of innovation in lithium-ion battery technologies and increase in electric vehicle production and development by different car manufacturers. This has been supported by increasing environmental awareness by the public and people are more interested in electric vehicles for their safety, innovative technology and low emissions. According to the briefing by Transport & Environment, many countries and major cities all around Europe have been discussing of banning or putting restrictions on the internal combustion engine vehicles (ICE), mostly diesel, and moving towards zero- and low-emission driving (Transport & Environment, 2018). The Finnish Ministry of Communications and Transport has published a report which introduces ways how to decrease CO2 emissions in road transportation in Finland and electric vehicles play a key role in the future of transportation.

Currently the sales of electric vehicles are increasing, and they are gaining popularity. But the models are still more expensive than ICE vehicles and the range and charging infrastructure are still developing further. The battery technology is expected to be developed further and by 2025 it is estimated that the price of EVs will become competitive with the ICE cars (Bloomberg New Energy Finance, 2018).

Charging infrastructure in Finland and in Europe has been developing fast. In shared apartment houses in Finland the charging infrastructure is not yet very popular, and this is a problem in the development. Many houses in Finland do not have enough capacity required for EV charging without substantial work in the electricity system of the house. The public charging stations are increasing rapidly, and more fast charging outlets are becoming available for charging on the road in Finland (Fortum, 2018) but still more is needed. In the future, the electrification of transportation will increase the consumption of overall electricity, but the Finnish electricity grid is well capable of handling it (Ministry of Transport and Communications, 2018).
Because the number of electric vehicles is expected to increase in Europe, it is important to make investments now. Establishing a long-term strategy and starting implementation with short-term actions to make passenger transport more electrified and better for the climate. Finland has been active in adoption of new technologies in transportation but been slow to increase the adoption of EVs. Finland is planning to have carbon-free transport by 2045 (Ministry of Transport and Communications, 2018) and this will require new laws and changes in policy to support that. Some changes are already being made in terms of incentives and tax supports for purchasing a new EV, but this is not enough, and more must be done in the future.

The fast growth of EVs will require expansion in the mining of raw materials, refining and in battery production. It is estimated that there is enough lithium on the planet to supply for the demand of transportation industry (Grosjean, et al., 2012), especially when secondary supplies of lithium became available. The problem might be in the raw materials mining and refining capacity and the question is can the production keep up with the demand. Supply of other raw materials, such as cobalt can be more difficult and cause bottlenecks in the industry. European Union needs to develop efficient supply chain for manufacturing electric vehicle batteries and ensure the availability of raw materials. Currently different organisations within EU are looking for new battery mix solutions through technology and innovation, and also new ways to produce electric vehicle power sources (European Commission, 2018).

Terms “Electric Vehicle” (EV) and electric car are used in this paper as generic terms for both fully electric battery-, plug-in electric and hydrogen fuel cell vehicles. The author’s personal interest for the topic developed during a six-month trainee period in Nissan Nordic Europe Oy as General Affairs, where introduced to the technology of electric vehicles, such as Nissan Leaf and others.

1.1 Objectives and research questions

The purpose of this research is to investigate the possible growth scenario of electric vehicles in Finland and analyse the report by Ministry of Transport and Communications while identifying key aspects regarding the topic. Discussing the adoption of electric
vehicles in Europe and to understand the difficulties related to the technology, battery materials and infrastructure.

This thesis is concentrating into the passenger zero- and low-emission vehicles. Figure 1 visualises the main ideas behind the topic and subjects related. In figure 1 we can see that the main issues concerning are in the battery production, regulatory framework (incentives and policies) and EV price. The significance of the topic is clear, and the automotive industry is going through a change to become electrified in the future. The topic relevant to the current discussions about climate change and environmental friendliness. European Union is committed to the goal of limiting global warming under 2 °C (European Commission, 2018). This research will not try to predict the future but instead, focus on the different outlooks of the future.

Figure 1 - Conceptual framework figure identifying the ideas around the topic.

The thesis statement is that the electric vehicles are inevitable part of future passenger transport, both in Finland and in Europe. Electric vehicles play a key role in reducing CO2 emissions. However, the growth of electric vehicles won’t be easy. The thesis paper is focused on explaining the issues regarding growth of electric vehicles in
European level and evaluating different methods how electric vehicles growth can be increased in Finland. In order to form sufficient understanding of the topic this paper will intend to answer the following questions listed below.

**How electric vehicles growth can be increased and supported in Finland?**

This provides the reader a knowledge of different methods how EVs growth is planned to be increased in Finland and identifying the measures already being in use.

**What are the issues and possible restrictions on the growth of electric vehicles?**

Aims to explain more in detail what are the issues related to the technology, battery materials and production of batteries. Helping to understand why it won’t be easy to change from traditional ICEs to EVs.

**How is European Union supporting the change to electric vehicles?**

The policies set by the European Union will affect the local policy making and practices in Finland. Therefore, European Union shows the way with research, innovation and with different policy making.

**Can the battery production keep up with the increasing demand of automotive industry?**

As lithium consumption has increased by 73 percent from 2010 to 2014, the production of lithium achieved growth of only 28 percent during the same time (Olivetti, et al., 2017). It is important to understand difficulties behind the EV battery production.

**How does the future of driving look like?**

The automotive industry’s future is expected to be more electric and it is important to understand what possibilities there are in the future of mobility.
1.2 Demarcation

The primary focus group of this study are the people who are considering buying an electric vehicle today and in the future. The aim is to give information and explain electric vehicles in more specific. This paper will also provide useful information to different entities such as charging network companies, car dealers and anyone who might be interested in the development of electric vehicles in Finland and in Europe. Research will be limited to passenger electric vehicles and will not discuss other type of electric vehicles such as railway, aviation and freight transport or public transport units.

1.3 Research methodology and data collection

This thesis is literature based and made using qualitative research methodology. The topic is approached by analysing the information currently available and making conclusions based on that. There are many relevant sources of information regarding electric vehicles, battery raw materials and production, future of transport, and reports about different methods how to decrease CO2 emissions in transportation. This research will use secondary data as the main source of information. Electric vehicles technical data will be taken from appropriate sources e.g. car manufacturer's websites, existing reports and scientific papers. The research method is chosen due to the nature of the topic and because there are quality information already available.

After preliminary research, the base assumption is that the electric vehicles are going to be very popular and their demand is going to increase significantly in the future. Taking in consideration that discussion about modern EVs (with the current lithium battery technology) is still relatively new and the topic is developing, the main focus is to use as fresh as possible information that is currently available. The thesis topic was also inspired by reading reports by European Commission and The Finnish Ministry of Transport and Communications published in 2018, in which is explained a plan how to reduce CO2 emissions in road transport and explaining how electric vehicles play a key role in the future of transportation.
Reader should take in note that some of the views on electric vehicles may be influenced by the authors’ experience working in Nissan. This experience provided a good basic level of information and created a better understanding of electric vehicles and charging infrastructure in Finland, but also some ideas why the increase of electric vehicles may not be easy.

1.4 Research material

The following reports have provided current and quality information and acted as one of the main sources in this research: The European Commission report: Final Report of the High-Level Panel of the European Decarbonisation Pathways Initiative from 2018 and Report on Raw Materials for Battery Applications; The report by Ministry of Transport and Communications report: Action programme for carbon-free transport 2045 - Final Report by the Transport Climate Policy working group from 2018.

Other main sources of information were the Nordic EV Outlook 2018 by International Energy Agency; relevant articles by Bloomberg New Energy Finance 2018 and 2019; Transport & Environment report: How to decarbonise European transport by 2050; Research by VTT Technical Research Centre of Finland on the market outlook for electric cars and gas vehicles in Finland 2018. The research is not limited to only these and other sources used can be found in the bibliography list at the end of this paper.

2 The basics of electric vehicles

Electric vehicles can be divided into different types, depending on the use of electricity in their power train. An electric vehicle is a vehicle that is driven by an electric motor which draws its electricity from battery or fuel cells. These vehicles can be zero- or low emission.
2.1 Battery electric vehicles

Battery electric vehicles (BEVs) are fully electric vehicles and use only electric battery to power the drivetrain. The car does not have a fuel tank, gearbox or exhaustion pipe which allows the car to have other functional benefits.

Benefits of a battery electric vehicle:

- Low cost of driving. Generally speaking, the assumption is that electricity used to charge an EV costs much less than refuelling ICE car. BEV batteries are much more energy efficient: An electric motor is typically 80 percent more efficient to convert the energy to power the wheels, compared to petrol powered engine, which then is only 20 percent efficient (Clean Technica, 2018).

- Cheaper to maintain. Because BEVs have a lot of fewer moving parts and less components that need to be replaced over time, it makes it much cheaper to maintenance than conventional ICE cars.

- Safer to drive. The battery of a BEV is heavy and are usually fitted to the floor (Nissan, 2018). This offers more safety because the structure of the battery gives support to the car chassis and lowers the point of gravity, making the car more stable to drive.

- Zero emission driving. The actual driving of BEVs does not produce any CO2 emissions. However, there are indirect CO2 emissions created by manufacturing and charging of EVs and this depends on how the electricity used to charge is vehicle is created. For example: If the electricity is produced from hydro power, it produces less CO2 emission per kilometre than the energy produced by coal and other fossil materials.

- Reduction of noise pollution. The electric vehicle produces very little noise from the engine and is much quieter to drive than ICE vehicles. This can also make the driving experience better.
2.2 Hybrid electric vehicles

Hybrid electric vehicles (HEVs) are powered by both petrol and electricity. The electricity is generated by the car’s regenerative braking system to recharge the battery. How it works is that the car first uses the electric motor on ignition and at low speeds, then when the need for power or speed increases, the petrol engine will start and produce the needed drive power (Nissan, 2018). The two engines are controlled by internal computer system which ensures low fuel consumption and the most economical mode of driving.

2.3 Plug-in hybrid electric vehicles

Plug-in hybrid electric vehicles (PHEVs) are powered by both petrol and electricity and like HEVs, it has two engines. Also known as “Extended-Range Electric Vehicles” (EREVs). PHEV is currently the most sold type of electric vehicle in Finland and may act as bridge towards fully electric vehicles. The vehicle battery is recharged by plugging-in to an external electrical charging outlet, like a wall box or household 240V socket outlet, and recharging can also be done by regenerative braking while driving. The main engine used in PHEVs may vary, depending on the vehicle’s choice of primary energy source. Some models use more petrol and others more electricity. This makes the car ideal for city driving and for short distances where it can run only by electricity. But when needed the petrol engine offers extended range of driving for longer distances.

2.4 Fuel cell electric vehicles

Fuel cell electric vehicles (FCEV) run on compressed hydrogen and are considered to be zero emission vehicles because the vehicle is emitting only water. Fuel cells convert hydrogen to electricity by using chemical reaction which then powers the electric motor. In current models the hydrogen is stored on-board with high pressure. European Commission estimates that beyond 2020 some alternative storage technologies could emerge, which would allow use of lower pressure storage enabled through cryogenic systems or by novel bonding materials (metal hydrides and sorbents).
This would improve the safety and reduce the cost of the vehicles (European Commission, 2018). Today FCEVs have equal range to ICE cars, which makes them more suitable for long range driving.

Hydrogen fuel cells represent alternative solution for electric vehicles in the future and they are important when considering the situation where fully battery electric vehicles alone may not satisfy all the need in the industry. But the integration of fuel cell technology and on-board hydrogen storage into a passenger car remains a challenge to many car manufacturers and currently only few models exists in the market. Refuelling infrastructure for FCEVs is even less developed than EV charging infrastructure, which means that the fuel cell electric vehicles are not yet very widely adopted. However, it is good that alternative options exist, and it could become more popular in the future.

2.5 Charging of electric vehicles

Currently there are three main ways of charging an electric vehicle. Charging of an electric vehicle requires the use of direct current (DC) electricity and most car manufacturers have installed inverter inside the vehicle that will convert the current from alternating current (AC) to direct current (DC) if needed.

Below the meaning for level is to describe the power output of the charging outlet. Type is referred to the plugin connector and socket being used for charging.

**Level 1.** This level of charging is for recommended for temporary use only. Charging is available at home or at public charging stations. Charging is done by plugging the charging cable directly into 230V outlet. This is the slowest type of charging and is not recommended for long periods of time because the normal household socket is not built for EV charging. Some household sockets may not be capable of handling constant high-power demand and in the worst-case scenario could burn the fuses. The charging cable is usually included with the vehicle and provided by the manufacturer. Time to full charge can take up to 10 - 41 hours, depending on the battery size (kWh) of the vehicle.
**Level 2.** This level of charging requires installation of charging outlet and is meant to be the main type of charging for electric vehicles. This is the most stable type of charging and is recommended for everyday use. Charging is done plugging in the charging cable to the charging outlet or smart wall box. It is very common in the Nordics to have charging outlets available at work and people can charge their vehicle during the day. But most of EV owners prefer to use their own wall box at home. To charge at public charging stations, you need NFC-Card or RFID-tag which acts as identification and will add the cost of electricity used to the user’s expenses. In Finland most of charging RFID-tags and wall boxes are provided by Fortum, Ensto and Virta and their pricing may differ with each other. Time to full charge can take up to 4 - 12 hours, depending on the battery size (kWh) of the vehicle.

The charging can be done with type one or type two cable. Type one connector cable (as seen in the figure 2) is used in the United States and in most electric vehicles manufactured by Japanese. The connector enables single-phase current up to 80 amperes. In this case the charger located inside the vehicle will convert the current from AC to DC.

![Type 1 charging plug and socket](image)

*Figure 2 - Type 1 charging plug and socket (PlugIt, 2018).*

Type two connector (see figure 3) cables are used in most European electric vehicles and the connector enables three-phase current up to 63 amperes, however usually limited to 32 amperes in general use. This is the standard type of cable used in Finland (PlugIt, 2018).
The cables are usually included with the vehicle or can be bought separately.

**Level 3.** This level of charging is the fastest charging method. Charging can be done at home, work or at any public charging stations which is equipped to the fast charging capability. To use the fast charging, you need to have a vehicle that supports the feature and a specific type of cable(s). The most common type of cables are CHAdeMO (see figure 4), CCS Combo and Tesla Supercharger. Fast charging provides direct current (DC) and the charging capacity is usually 50kW but can be up to 350kW with current technology. The fast charging is increasing in popularity and will most likely to become the main method of charging at public charging stations. Time to charge from 20 percent to 80 percent can take up to 40 - 90 minutes, depending on the battery size (kWh) of the vehicle.

Figure 3 - Type 2 charging plug and socket (PlugIt, 2018).

Figure 4 - CHAdeMO fast charging plug (PlugIt, 2018).
3 Decreasing CO2 emissions in driving

3.1 Ministry of Transport and Communications report

In early 2018 the Finnish Ministry of Transport and Communications assigned a group of experts to draft a proposal for action. The purpose was to make an action plan for eliminating greenhouse gas emissions in domestic transport by 2045. This is in accordance with similar plan made by the European Union, which aims to eliminate most of the greenhouse gas emissions in its member states by 2050. This can be seen as major step towards change in the European Union and this is reflected in the member states as well. Now Finland has a plan of its own.

According to the report by Ministry of Transport and Communications, there would be 670,000 passenger electric vehicles by 2030, and about two million electric vehicles by 2045 in Finland. These estimations do not include heavy transportation units, such as trucks, buses and railway units. The report identifies two main milestones on the way, which are: the sales of fossil fuelled vehicles will become to an end in 2035 and the sales of fossil fuels will be prohibited after 2045.

The report by Ministry of Transport and Communications suggests different ways how to decrease CO2 emissions in transport and below is listed some the main methods regarding electric vehicles. These methods have effect on the popularity and demand of electric vehicles. They are also criticized for their efficiency and evaluated if they are efficient enough to support the estimations described in the report.

Incentive on purchasing a new zero emission vehicle

Purchasing or leasing a new fully electric vehicle will benefit from a discount of EUR 2000 for cars priced below EUR 50,000 (including VAT and registration tax). According to TrafiCom in 2018 only 776 new fully electric cars were registered. Ministry of Transport and Communications states that only about ten percent of the budgeted incentive amount was used in 2018. Therefore, the incentive has not been efficient enough, and the amount of the incentive should be higher, around EUR 4000-6000 per car.
In addition, the incentive should be made available for companies and cities and extended to all electric type of vehicles, including plug-in hybrids.

Support for charging infrastructure

The Finnish government has invested EUR 4,8 million (Korkia Consulting Oy, 2018) on building public charging infrastructure for years 2017 - 2019. The incentive aims to set in motion EUR 15 million worth of total investments and triple the number of public charging stations in two years (Korkia Consulting Oy, 2018). Incentive on investing in charging stations in shared housing from 2018 onwards has been EUR 1,5 million a year. The incentive was applied in 75 housing companies for 1200 applications of charging outlets in 2018 (Ministry of Transport and Communications, 2018).

Finland should set national target for the number of available charging stations in buildings, along public roads and urban areas (including street parking). As the public infrastructure is more easily developed, the incentive should focus more on shared apartments and public apartment buildings, where the installation is more difficult to implement. The support for charging infrastructure should be continued until 2030.

Changes in vehicle taxation

There are several different tax types affecting the cost of ownership and registration of a passenger vehicle in Finland once a new vehicle is purchased, the vehicle tax is paid. Vehicle tax is nonrecurring tax payment which happen only when the vehicle is first registered to Finnish vehicle register system TrafiCom. The tax value is based on the wholesale price of the vehicle and its CO2 emission per kilometre (Traficom, 2019).

The current vehicle tax amount is heavily based on the CO2 emissions of the vehicle. The taxation should be developed in a way that it favours the less polluting cars and at the same time gradually increase the tax on high polluting cars. The report by Ministry of Transport and Communications suggests a model in which the vehicle tax would be removed and where electric vehicle purchase incentive would be supported by the payments collected from high-emission cars. This would then increase the motivation to
buy less polluting vehicle, rather than a high polluting one, where the owner needs to pay more over time in the future.

Tax on motor vehicles is the second type of tax which is applied on daily basis but paid in 12-month period. The tax is paid by the current owner of the vehicle and if the vehicle is registered to new owner today, the new owner has to pay for the current year. Amount of the tax is consisted of two parts; the first part is base amount and is determined by the CO2 emissions created by the car. The second part is from propulsion and power of the car. The more powerful and polluting the car is, the more has to be paid (Traficom, 2019). Cars using fossil fuels are more heavily taxed compared to similar models with hybrid or electric engine.

Tax on fossil fuels

The consumption of fossil fuels is directly connected to the created CO2 emissions and therefore the consumption should decrease. The report estimates that the most effective way to decrease CO2 emissions is to increase the tax on fossil fuels, especially diesel. The amount of fossil fuel tax should be gradually increased while introducing other incentives with the aim to shift drivers towards alternative means of transport e.g. low- and zero-emission vehicles.

Most of emissions are created by the usage of the vehicle when fossil fuels are used as the energy source. Taxation should move towards supporting low- and zero-emission vehicles.

Campaign for scrapping old vehicles

There have been incentives for recycling old cars in the past, but the campaigns have not been continued after 2018. In order to receive the incentive of EUR 1500, the car had to be 10 years old and the user had to purchase a new car producing less than 110 g/km CO2 emissions in 2018 (Ministry of Transport and Communications, 2018). Aim of the incentive was to reduce the stock of old cars in traffic and support purchasing a new less polluting car. When the incentive was implemented in 2015, 17 percent more of the
old cars were recycled than year before in 2014 and only about 10 percent of the cars would have ended up recycled without the incentive (Ministry of Transport and Communications, 2018). Therefore, these incentive campaigns have been successful and should be continued. Rules for granting the incentive should be less strict regarding the specifications of the old car that will be recycled and rule for the new car should be that it is electric. Introducing new rules for the incentive could activate more people to get rid of their old cars and help renewing the car stock towards more electric vehicles.

Advising electric vehicle purchasing

The new electric engines, battery electric vehicles, plug-in hybrids, hybrids and other electric vehicles can be difficult to understand, and people should be advised when purchasing a new vehicle. Some might not realise the total cost of ownership or CO2 emissions, when deciding to purchase a new car and they should be guided with information and explained more about the benefits of electric vehicles. There is already active discussions about electric vehicles in the news and in the newspapers, but there could be more.

3.2 Suggestions for development in the future

New incentives should be created and developed to support the growth of electric vehicles in Finland. The current incentives are unlikely to be enough to push passenger transportation towards fully electric and therefore government should do more, especially in development of charging infrastructure. It is also very important to acknowledge the rules that European Union sets for CO2 emission on new vehicles, because that will directly have effect on the car models becoming available in Europe and Finland. The stricter the rules are, the less polluting cars will be manufactured or brought to the market. EU investment on charging infrastructure is also very important for Finland and the Finnish government should take more advantage of this. Since without financial aid it is very costly to build charging infrastructure throughout all Finland as Finland is geographically a long country and it will need a lot of charging stations, even in less populated areas where building stations might not be otherwise economically profitable but necessary.
In the long-term renewing of car stock and car fleets in Finland is one of the main objectives and the renewal must become faster with increasing number of zero- and low-emission vehicles replacing the old ones. Because of limited availability and still relatively high price of fully electric vehicles, the short-term objective should be to encouraged people towards low-emission vehicles like plug-in hybrids and hybrids while keep the long-term goal to move towards zero-emission BEVs as main method of passenger transportation in Finland.

3.3 European Union and the electric vehicles growth scenario

The research made by European Commission focuses to explain actions, possible solutions and issues how to reduce European Union transport industry’s CO2 emissions. The research is made in accordance with the Paris Climate Agreement in restricting the global warming under 2 °C. The EU has plan to achieve zero net emissions of all greenhouse gases by 2050 while increasing the competitiveness of the EU’s economy and electric vehicles play a key role in the plan.

According to the European Commission, within the EU-28 Member States transport services were responsible for 26 percent of total domestic CO2 emissions in 2015. As Figure 5 represents, most of the emissions are created from road transport.
Passenger transport services were responsible for about two thirds of the national (European Union) CO2 emissions created by transportation. Renewing the stock of old cars on the road and moving towards zero- and low-emission vehicles is significantly important in European Union.

The report highlights some of the challenges in technical, regulatory and economic development. There is much to be developed in charging infrastructure, system hardware standardization, service providers and standard protocols. Current public charging infrastructure in Europe is still developing and there is not enough fast charging stations available. There are also many differences in the service providers that are available. European Union wants it to be easier for consumers to charge their electric vehicle and the drivers should be able to choose their charging provider much easier, instead of having five to ten different charging payment providers and many different charging tags, that will only make the driver more confused. The charging plugs are being required to be standardized in the EU. The problem with too many different EV charging system hardware’s, service providers and payment methods should be solved because these could create compatibility issues with different electric vehicles.
Consumer behavior is needed to be studied more in order to better understand the decision making of car purchasing and the use of information in appropriate campaigns and implement the knowledge by creating better incentives. Low- and zero-emission vehicles are recommended to become default option in new car purchases in the future. Establishing a set of regulations that will guide drivers towards less polluting cars will be beneficial in the long-term for the European Union. European Commission is planning a new regulatory framework to be set for the electric vehicles, concerning the electricity network and charging of the vehicles, which would also solve the difficulties with the charging providers mentioned earlier. The regulations regarding the vehicles which use fossil fuels are expected to be more stricter and policies are updated to increase electric vehicle adoption in Europe.

4 Growth of electric vehicles and infrastructure

4.1 Growth of electric vehicles in Finland

The growth of electric vehicles in Finland has been positive in the recent years and since 2013 the growth has increased exponentially, from 465 to 15499 number of EVs in 2018 (TrafiCom, 2018). The current stock of EVs is dominated by plug-in hybrids as 84 percent were PHEVs and only 16 percent were battery electric vehicles in 2018 (TrafiCom, 2018).

Electric vehicles in Finland are divided into different usage types. Most common type is private ownership of the electric car. Second type is leasing of an electric car through employment or directly from different leasing companies. The third type, which is not yet that popular in Finland, is the use of electric vehicles in shared mobility. As the ownership of a car is relatively expensive and will likely become even more so in the future, the use of private leasing and shared mobility is expected to increase (PwC, 2018). This can mean that the trend is moving towards mobility services and private leasing, rather than owning a car yourself.

Policies supporting electric vehicles have significant influence on the adoption of electric vehicles in Finland. Finnish people are very price sensitive when purchasing a new car
and a car is seen more as tool used to travel from point A to point B, rather than an entertainment or driving experience. Policies and incentives that reduce the purchase price and cost of ownership of electric vehicles will make the most difference. The Finnish people also pay close attention to different measures how to reduce costs through taxation, and if the taxation laws are changed in a way that people can benefit from owning an electric vehicle, they are more likely to purchase one. There was a lot of talk about environmental friendliness in the recent general elections of Finland and the new government should take in close consideration the report made by the Ministry of Transport and Communications and take appropriate actions. Implementation of new laws and incentives should be planned properly but without delaying the decision making for too long. The second most important factor for EV adoption in Finland is the charging infrastructure and this should continue to develop as planned. Other benefit that Finnish people appreciate is free parking, and the early adopters of electric vehicles have often access to parking that is equipped with charging availability.

The Finnish people are very interested in electric vehicles and in new technical features they will introduce in the future (e.g. autonomous driving, safety and socially linked apps etc...) but at the moment the price is too high for many and the driving range of the vehicle is too short. These are the most limiting factors in decision to buy an EV. In addition, some may feel that the charging infrastructure is not sufficient enough for their needs. And because the development of electric vehicles sales in Finland is very slow, the goal of 670 000 EVs by 2030 seems unlikely. The sales are expected to grow but not as fast as predicted. Maybe after the sale of fossil fuelled cars are prohibited, the EVs will see dramatic growth to become as popular as ICE vehicles are today.

4.2 Growth of electric vehicles in Europe

The traditional ICE cars are seeing major regulatory changes in CO2 emissions and car manufacturers are struggling to keep up with it. Developing an internal combustion engine to meet the new regulations every time is very expensive, which has driven the European car manufacturers to invest in electric motors and battery technology.
Electric vehicles annual sales in Europe has been 168,000 units on average (EAFO, 2018) in the last couple of years. In 2018 electric vehicles represented a market share of around 2 percent of total car sales with 408,000 sold units (EV Volumes, 2018) and currently there are about 155,000 public charging stations in Europe (EAFO, 2018). The sales are estimated to grow up to 7 percent in 2025 (equivalent amount to about 20 million cars) and the number of charging stations across Europe is estimated to grow to more than two million (European Commission, 2018).

4.3 Charging infrastructure in Finland

Charging infrastructure has seen growth in development in Finland for the past five years and the number of public charging stations are increasing. Today there are 722 publicly available charging stations and 138 of these are fast charging (Teknologiateollisuus, 2018). In each charging station there are two outlets for charging. Currently the charging stations are not distributed equally throughout Finland, as most of them are concentrated on larger cities where most of the customers are. At the moment 48 percent of charging stations are concentrated in the area of Helsinki, Tampere and Turku (Teknologiateollisuus, 2018). Rest of the charging stations are scattered across Finland.

In general, the current usage of public charging stations is relatively low and recent surveys conducted by International Energy Agency indicates strong consumer preference towards home charging. But public charging stations are very important part of the ecosystem as they allow people to travel longer distances and ensure interregional access. Public charging stations are essential for electric car owners who do not have access to reserved parking or possibility of home charging. The European Union directive 2014/94/EU recommends having at least 1:10 public charging outlets to EV ratio (European Commission, 2018). Today the ratio is 1:8 in Finland and is in accordance with the national target of 2000 public charging outlets by 2020 (Teknologiateollisuus, 2018).

The readiness for home charging in Finland is relatively good since theoretically the car can be charged through the car heating outlets or the heating outlets can be changed to EV charging outlets. Most of the Finnish household parking lots are equipped with the
electrical outlet for engine heating and in most cases the outlet capacity is 1-2 kW, which is capable of slow charging of the electric vehicle. However, it is recommended to use charging outlet specially designed for electric vehicles, because the normal electrical outlet might overload the household grid. Reason for this is because the normal heating outlet is not capable of adjusting the electricity flow used in the charging. In detached households the user can have possibility to upgrade for smart wall box which can adjust the electricity power flowing through the outlet and do the charging in much safer and faster way.

In shared apartment buildings where the ownership is distributed among the owners, it might be more difficult to upgrade to charging outlet since the investment decision needs to be made by the all of the owner(s). This is currently a problem as it can affect the purchase decision of an electric vehicle for a person living in shared apartment building. The issue is tricky because the household owners might not feel the need to invest in charging outlets, because there are not enough electric vehicle owners in the household. Therefore, a person thinking of purchasing a new car might not buy an electric vehicle, because the household decided not to build charging outlets. It can be that the main reasons leading to rejection in investment are the lack of general knowledge of electric vehicles and charging infrastructure, disagreement on the costs or budgeting of the funds. Distribution of costs can often be an issue in the case where only a few people need the charging outlet, and when investing to build those, everyone has to pay for it. In older buildings it can be the lack of building’s capability to sustain EV charging, meaning that the building does not have sufficient electricity systems in place to sustain the energy required for EV charging. European Union has recognized these problems and is developing regulations which addresses shared housing and charging outlet installations. There is already a regulation that requires EV charging to be possible in new buildings and a specific type of buildings e.g. offices and publicly founded apartment buildings.

People living in urban areas and city centres whom might not have possibility of home charging, could be compensated by establishing more fast charging stations available at city centres. This way a person can own an electric vehicle and do the charging at the
fast charging station once a week. However, this might not be good enough for everyone who prefer home charging.

4.4 Electricity grid network in Finland

The electrification of transport is increasing the consumption of electricity, as more public charging stations are increasing, and more fast charging outlets are becoming available for charging on the road. This is estimated to increase the consumption of electricity overall. It is estimated that Finland is capable of producing the electricity needed for EV charging and even if the EVs increases as estimated in the Ministry’s report, it would add about one terawatt hour (TWh) of electricity consumption to the Finnish electricity grid. As history has shown, Finland has strong electricity grid network, as it is built to serve high electricity demand during the winter times. Even if all the 2.6 million cars currently registered in Finland (Traficom, 2019) would be electric, it would not increase the electricity consumption higher than the consumption of year 2007, which was record high over 90 TWh (Ministry of Transport and Communications, 2018).

Finland is relying on diversified energy, which includes a major share of nuclear power and a sizeable portion of energy co-created by biomass combined with heat and power plants (Nordic EV Outlook, 2018). The carbon intensity of electricity created in Finland is lower than the average in the EU (Nordic EV Outlook, 2018). This means that the electricity production in Finland is mostly low carbon based, which makes charging the electric vehicles to have significantly lower climate impact. The impact will continue to decrease even further once Finland will be able to phase out use of coal and other fossil-based material in energy production. Therefore, the energy production is already supporting the change to EVs and will continue to do so even more in the future.

5 Battery production and raw materials

Batteries are the key element enabling the technology for electric vehicles and energy storage. Battery chemistry is being developed to become more efficient and improvements in the energy density of the battery packs have been made. Lithium-ion
battery applications in the electric vehicles are growing rapidly, resulting in increasing demand for battery raw materials. Currently the four most essential raw materials for battery production are: lithium, cobalt, graphite and nickel. Other important raw materials are manganese, aluminium, copper, tin, silicon, magnesium, germanium, indium, antimony and other rare earth elements (Olivetti, et al., 2017). The vehicle’s battery is made of pack of batteries that require a minimum of 16 kg of lithium carbonate per each pack (Grosjean, et al., 2012).

Current lithium-ion battery pack price is $176/kWh and the price is estimated to continue decreasing to $94/kWh by 2024 (Bloomberg New Energy Finance, 2018). Manufacturing price of lithium-ion battery packs is mostly affected by the supply chain of materials, logistics and manufacturing plant processes. Developing efficiencies in these areas is needed to make the price of battery packs to decrease. The suspicion on availability of raw materials and increasing demand can drive up the price of key battery materials like cobalt, lithium and nickel, which then could potentially impact the price of the battery packs in the future. However, the car manufacturers are unlikely to let the manufacturing price of the battery packs to increase and affect the consumers prices of the vehicles, since one of their goals is to make electric vehicles cheaper. Assumption is that the battery price is the most defining factor making electric vehicles more affordable to the consumers and price competitive against ICE vehicles.

Raw materials like lithium and cobalt are currently the ones people are talking the most about. The supply chain of these materials is potentially vulnerable to disruptions and shortages that can affect the large-scale production of battery electric vehicles (European Commission, 2018). This raises concerns about the availability of critical raw materials and the long-term sustainability of battery production in general.

Creating a competitive and sustainable battery manufacturing industry in Europe is highly important. The EU has created a plan to address this challenge by establishing: (1) sustainable sourcing of raw materials from global markets, (2) sustainable domestic raw materials production, and (3) resource efficiency and supply of secondary raw materials, by establishing efficient recycling processes (European Commission, 2018). In order to catch up with the Asian rivalry, Europe need to develop to be better in every step of battery value-chain, starting from supply of raw materials to the manufacturing industry.
There is a real motive behind, because European Commission has estimated that Europe has the potential to capture batteries market of up to EUR 250 billion a year, served by 10 to 20 gigafactories’ by 2025 (European Commission, 2018).

New battery material chemistries are under investigation by European Union, such as lithium-nickel-manganese-cobalt and lithium-nickel-cobalt-aluminium oxide, which both aim to reduce the amount of cobalt used (European Commission, 2018). In European Union level, further investments are needed to find alternative solutions. According to Tesla they have significantly reduced the cobalt content per battery pack while increasing nickel content and still maintained superior thermal stability. The company estimates to be able to reduce use of cobalt to almost zero (Tesla, 2018; The Financial Times, 2018) and the European car manufacturers should aim to do the same.

In the future more research and development should be focused on sustainable ecosystem for both existing and new battery technologies with efforts to achieve technology readiness level of all-solid-state lithium-ion batteries.

5.1 Competition on battery raw materials and production

The mining of raw materials, refining and battery production is relatively concentrated and most of these three processes happen outside of European Union. According to European Commission report from 2018 on raw materials for battery applications, the main suppliers of battery raw materials for European Union are across the globe: nickel from Russia (19 percent), natural graphite from China (66 percent), Manganese from South Africa (30 percent), copper and lithium from Chile (21 percent and 66 percent), and cobalt from Finland (66 percent). Most of the EU mineral exploration activities are concentrated in Portugal, Finland, Sweden and central Europe and the only EU country with cobalt mine production and refining process is Finland. The production of cobalt in Finland represents only 1 percent of global production, which is far from enough for the European car manufacturers (European Commission, 2018).
Concentration of cobalt production

Globally, cobalt is mined in 19 countries with the largest producers located in the Democratic Republic of Congo, China and Canada as seen in figure 6. Cobalt is mostly extracted as by- or co-product of nickel or copper mining (Olivetti, et al., 2017).

![Global Cobalt mine production chart]

Figure 6 - Concentration of global cobalt mine production (European Commission, 2018).

The Democratic Republic of Congo is known for lack of environmental protection and exploitation of human labour (Anderson, 2018). Many battery and car manufacturers aim to reduce use of cobalt in their batteries for ethical reasons but also to reduce the risk of supply chain disruptions due to the concentration of the raw material.

Challenges of European access to lithium

Lithium reserves are spread across the globe with the most found reserves in Latin America and regions of Australia and Asia (Grosjean, et al., 2012). The concentration of lithium resources is creating geostrategic- and logistic bottlenecks. Some of the countries may be into nationalizing the lithium exploitation and could have planned actions on lithium prices which then would make it more expensive for Europe to acquire. Australia, Asia and North America will presumably have a balanced trade between the lithium
production and consumption within their region and this leaves Europe in less advantageous situation (Grosjean, et al., 2012). Because Europe has only less than 3 percent of the global lithium resources, it makes it very dependent on importing resources outside. The distribution of lithium resources is very contradicted and much of trade imbalance is expected occur. Conditions of free market and free trade between the countries supplying and the countries consuming lithium as raw material would be most desirable, but in reality it does not happen. Before new mines and raw material production in Europe has been established further, the current trade imbalance of lithium will affect the European electric vehicles manufacturing industry in the years to come.

Mining of lithium and global resources

To understand why new lithium resources are not so easy to establish, it is important to know more about the lithium mining processes. Lithium carbonate is today mostly sourced by mining or extracting and is treated from two main sources: spodumene ores and salt-lake brines (Grosjean, et al., 2012). Spodumene is a lithium-rich ore that is contained into a special type of stone called pegmatite. Production cost of spodumene processed lithium carbonate is 6-8 $/kg (Grosjean, et al., 2012). Salt-lake brines are water resources with high concentrations of mineral salts. This extradition process is environmentally friendly as it only relies on having the brines pumped and evaporated under the natural effect of the sun. However, establishing new salt-lake brines is very slow and it can take up to two or three years to have lithium carbonate ready for sale and even after that the lithium carbonate needs to be processed for usage in the EV industry (Grosjean, et al., 2012). Production cost of salt-lake brine processed lithium carbonate is slightly cheaper than spodumene processed, with a price of 2-3 $/kg (Grosjean, et al., 2012).

Figure 8 illustrates the concentration of lithium resources in 2012, which implicates that Europe does not have much found lithium resources. It is important to remember that any current mining or new mining, exploitation and treatment processes of lithium are environmentally sustainable and have carbon impact as low as possible, especially below the equivalent levels of ICE vehicle production.
Establishing battery manufacturing in Europe

The battery manufacturing industry has been concentrated in Asia. Current production in China, Japan and Korea constitutes to 85 percent of manufacturing capability of lithium-ion batteries for all end-use applications (Olivetti, et al., 2017). European Union is working on industrial projects with different entities to create a competitive battery manufacturing industry of its own. New battery manufacturing plant is set to be built in Sweden by Northvolt. The project is part of European Battery Alliance and coordinated together with the German car manufacturer BMW and industrial conglomerate Siemens (European Commission, 2018). When starting production, the plant will become Europe’s biggest lithium-ion battery factory with capability of producing 32 gigawatt hours (GWh) of battery cells a year by 2023 (Northvolt, 2018). Northvolt is planning to build another factory in Poland to produce battery systems for energy storage and for mining industry. Other European car manufacturers like PSA and Volkswagen have announced to establish battery cell production in the future (Nienaber, et al., 2019). The German Federal Ministry for Economic Affairs has published a subsidy programme of one billion
euros to set up cross-border battery cell production and the French government has announced to support this with contribution of 700 million euros (Hampel, 2019).

It will be very difficult for Europe to compete with the battery industry in China, since it is way ahead in most factors such as raw materials, refining and production of batteries. China has strong position on the production of natural graphite, having 69 percent of global production and majority of the world’s lithium refining facilities are located in China. China has also steadily increased control of mined cobalt production. All this is making the lithium-ion battery industry even more concentrated in Asia and creating more pressure for Europe to secure steady availability battery raw materials and supply. It will not be easy for Europe to mass produce electric vehicles for the future demand.

However, it seems that the European battery manufacturing is beginning to take its first steps and many projects are on the way. This makes it look promising for European car manufacturers in the future, but it remains to be seen can the projects be completed in time and companies start production early enough to capture the value that lies in the battery manufacturing.

5.1.1.1 European Battery Alliance

In 2017, the European Commission launched an alliance to ensure that Europe has the capabilities to benefit from the estimated EUR 250 billion battery market by 2025. Main priorities of the alliance is to secure sustainably produced battery raw materials at reasonable cost, by securing access to sources outside the EU, facilitating the expansion of mining exploitation, ensuring research on European sources of raw materials and creating circular economy of batteries by efficient recycling of raw materials. According to the European Commission, the alliance’s aim is to make Europe the global leader in battery technology by creating competitive value chain for batteries.

Establishing Europe’s own raw material sources are essential for the future competition of raw materials. Therefore, European Union is planning through the alliance to map out and explore available raw material sources in Europe, to ensure the sustainable flow of raw material to European car manufacturers. European Union needs to carefully develop
new mining exploitations and take in account the environmental impacts of mining activities. Diplomatic relations with the current supplying countries are also a key aspect in securing the supply of battery raw materials.

5.2 Can supply meet the demand in the future?

The car manufacturers have set high estimations on the sales of their EV models and the trend for e-mobility is booming. However, after studying the supply chain of battery raw materials, question arises: can the battery production keep up with the demand?

To give some perspective, here is an example of a case where the supply chain caused disruption in the production: In April 2019 a large European car manufacturer had to reduce their production target for their new EV model and postpone production of their second model to 2020, due to supply issues in battery production. Reportedly, the battery manufacturer was having production difficulties, but unfortunately the source of the news did not specify why. Although this was only one case, it demonstrates that there is a risk of battery production not meeting the demand at sufficient level to support the sales of EVs. Considering the estimated increase in electric vehicles in Europe and in Finland, even more difficulties could exist in the future.

Current state of resources estimates that there is no danger to run out of lithium on the planet (Grosjean, et al., 2012). But there is a risk that lithium is not recovered and refined fast enough to be used by the EV industry increasing demand. The efficient level of producing lithium-ion batteries at sufficient scale has been questioned. The increase in demand of lithium is expected to be significant in years to come and the industry has to be able to keep up with it. EV industry is expected to be the most consuming user of global lithium resources in the future and Bloomberg New Energy Finance estimates on their outlook that the supply chain of lithium could have difficulty to meet the demand in the early 2020’s already. But the situation could also be less critical in the future, as mining and production companies will expand their production and start new facilities. However, the processing capacity of battery-qualified grade materials such as lithium carbonate and lithium hydroxide monohydrate will remain a bottleneck, as currently only
few processing companies have the capacity and ability to produce high-grade lithium compounds that the batteries need.

Cobalt is also being criticized as critical raw material for lithium-ion batteries. Based on Bloomberg’s analysis on the demand of battery materials, there will be shortages of cobalt by the early 2020s as well (Bloomberg New Energy Finance, 2018).

The supply chain of cobalt could be at risk, because the material is concentrated in politically very unstable country. The political instability in the Democratic Republic of Congo and other factors like epidemic disease could affect the supply chain.

Manufacturing of lithium-ion batteries

Global lithium-ion battery manufacturing capacity today is around 290 GWh per year and based on announcements and estimations on new manufacturing plants to operate, the capacity is to grow over 400 GWh by 2021 and over 1000 GWh by 2024 (Bloomberg New Energy Finance, 2018). This increased capacity is equivalent of annual production of 20 million EVs with an average battery size of 50 kWh each.

According to article about lithium-ion battery supply chain by Olivetti, et al. (2017) the mining production of cobalt and lithium needs to increase by more than three times for cobalt, to meet its estimated demand by 2025. Three and a half times for lithium, and the demand would then require 75 percent of global lithium production in 2025 going to EV industry. Meanwhile, the lithium consumption has increased by 73 percent from 2010 to 2014 while the production achieved only growth of 28 percent (Olivetti, et al., 2017). The global lithium resources and reserves are represented in the figure 7.
5.3 Recycling of electric vehicles batteries

In the past lithium-ion batteries have been regarded as hazardous waste but in fact, the recycling of batteries can serve as valuable source of raw materials. In the future it will be necessary to recycle as much as possible to secure the supply of raw materials for automotive industry. Recycling will also help to reduce the environmental cost of batteries because they are not treated as waste but instead, treated as resource. Using recycled materials also reduces the CO2 emission created by the battery production.

Recycling the used EV lithium-ion batteries in Europe is not yet at the level required to be very efficient. There is lack of knowledge how to do so and lack of information about the battery’s second-life usage. European Union is worried because the materials used in these batteries are very damaging and dangerous to the environment and should be treated properly. Vehicle manufacturers should be more involved by being active about the battery recycling and inform the consumers and different entities regarded. They should develop qualification and criterion for second-life usage of EV batteries and give out more information more about battery performance, reliability and safety when the battery is at the end of its EV life usage.
The Batteries Directive (2006/66EC) established obligations for Member States and industrial operators to maximise the collection of battery waste and ensure that all collected batteries are treated properly and recycled (European Commission, 2018). This will help to achieve high level of recycling and enable re-use of the battery raw materials in production again.

The total stock of secondary lithium has grown from 2010 to 2019 by 500 percent and in the same time, cobalt with roughly 200 percent (European Commission, 2018). This illustrates the potential of recycling and capturing the existing metals for new production. However, recycling processes in most countries are only at the minimum level of efficiency and only fifteen Member States (Austria, Belgium, Bulgaria, Croatia, Denmark, France, Finland, Germany, Hungary, Ireland, Lithuania, Luxembourg, Slovakia, Sweden and United Kingdom) are considered to meet the target of 45 percent of the collection of battery waste (Eurostat, 2018).

The problem to ensure efficient recycling is more likely to be related to logistical processes associated with the collection of battery waste, rather than with the efficiency of recycling itself (European Commission, 2018), but still further work and technological development is needed to better capture the full potential of existing battery raw materials.

Large-scale EV battery recycling is not expected to happen before 2020, because after that there will be more electric vehicles that have reached their potential end of lifecycle. It can be expected that the recycling will be more effective by 2025 since then the technologies and practices have developed more. Luckily, more companies have started to invest in recycling of used EV batteries in Europe (e.g. Umicore in Belgium and Recupyl in France). There are also number of EU funded research initiatives and pilot projects created for assessing the re-use of old EV batteries, such as Batteries2020, Energy Local Storage Advanced system (ELSA) and ABettReLife.

Some examples of EV battery second-life usage exists, for example: Nissan announced in June 2018, that they had created a power storage system made from 148 old Leaf batteries and solar panels. This system is being used to power a football stadium in Amsterdam. Their power storage system has life expectancy of 10+ years, which
increases the potential lifecycle of their EV batteries significantly. The company has also developed other solutions for used Leaf batteries, such as mobile back-up energy storage, which is powered by solar panels. It can be used almost anywhere on the road and it is made from old Nissan Leaf batteries (Nissan, 2018).

Because the technology is relatively new and it’s been only a decade after the current form of lithium-ion batteries begin to be used in vehicles, there is not much time related data and information about how sustainable the batteries really are or what their true-life expectancy should be. European Union and the car manufacturers should keep developing better ways to recycle and re-use the battery materials in circulation and develop standardized platforms for recycling.

6 Future of mobility

In the future the choice of passenger vehicle and mobility is much more based on the purpose of driving and the needs of the driver. If the person is living in the city and urban areas, it might be best to choose electric vehicle or use mobility services for daily commute. Electric vehicles are good solution for driving in city areas and if the vehicle is required to be driven longer distances, the importance of the charging network and better battery technologies will play an important role. In the future is it very likely that smart charging and energy storage devices are more common in the households and workplaces to enable EV charging. Other solution might be the use of hydrogen powered vehicles for longer distances. Currently the hydrogen fuel cell vehicles can deliver similar operational characteristics to those of diesel vehicles, in terms of torque, power, range and refuelling time. But to drive hydrogen vehicle for long distances, it would require much better hydrogen fuelling network than we have today. It remains to been if the fuelling network will continue to develop in large scale in Europe, but in Finland it is unlikely to happen due to the very low popularity of these vehicles.
6.1 Mobility services

Mobility-as-a-service, e-hailing, peer-to-peer car rental and car-pooling are becoming much more popular and generalization of these concepts reflects the trend that car ownership has become less attractive. In the future it is expected that these services will continue to grow. By 2040 it is expected that shared mobility would account for 19 percent of total kilometers traveled by passenger vehicles, and 80 percent of the shared mobility fleet would be electric vehicles (Bloomberg New Energy Finance, 2019).

Shared mobility allows people to be more connected and experience the mobility as a service. The service could provide customized recommendations and solutions for users by using user given data via an app. More people are more aware of the environmental damages generated by driving and may not be interested in owning a car or can’t simply afford one. Every year more mobility-as-a-service type of solutions emerge, and car ownership becomes less attractive solution for mobility. Transition to service-based mobility can be similar to the transition to online shopping, it is a change in consumer behavior.

Shared mobility services already exists in Helsinki, where companies like SHARE NOW and GoNow are offering shared mobility. You can rent a car via an app and use it for the time you need. It is expected that more companies like this will emerge and they offer mobility as one-time service to allow travel from point A to B. E-hailing services are already available and for example Uber is offering convenience in personal transport by enabling consumer to contract trips via an app.

Private leasing is expected to become more popular because it allows you to have a car without ownership and most importantly, without the large investment of buying a car yourself. A person making private lease contract pays only the monthly fee of using the vehicle and fuel costs. The terms of the contract are varying between different companies. Current companies offering the private lease service are: Kesko group’s K-Caara, Delta Auto’s Delta Drive, Laakonen’s FiksuDilli and Santander Finance’s All-In-1.
Electric vehicles are good solution for these kind of mobility services, since they are less polluting, require less maintenance and are well equipped for city driving. Use of electric vehicles in these mobility services is expected to be the main choice in the future.

7 Conclusion and recommendations

The future of passenger transport will be more electric and transition from ICE vehicles to electric ones is going to happen gradually over the next decades. At the moment the electric vehicles are only popular in the larger cities of Finland, due to the reason there are more charging stations available and daily commutes can be made without worrying about the range of the vehicle. As the charging network expands, it can be expected that more people in Finland will buy EVs, especially when the purchasing price is reduced and there will be better second-hand market of EVs available. In the future Finland needs increasing support for electric vehicles in the form of incentives and appropriate policies by the government, especially taxation should be adjusted to favour purchasing of zero- and low emission vehicles and motivate more people towards electric vehicles.

7.1 European Union

This paper recommends the European Union to keep investing more in the research of zero- and low-emission vehicles and in different technologies that support that. Innovation is needed to make batteries more efficient and price competitive. In the future Europe needs to ensure sufficient access to battery raw materials from other countries while exploring possible new production sites of their own. Establishing competitive battery manufacturing industry in Europe is going to be very difficult and it might be even too late for Europe to fully start competing against Asian rivals. However, developing the recycling processes and further technological developments of electric vehicles, including more efficient battery chemistries, Europe might gain a competitive advantage. It is important to keep investing in the supply chain of battery manufacturing to reduce the dependency to other markets. European car manufacturers should aim to work together by investing in shared gigafactories to produce vehicle batteries.
Manufacturers should take more responsibility in the recycling of batteries from the old vehicles and use it as an advantage. And significantly aim to reduce the use of cobalt in their batteries.

European Union should aim to create more efficient policies regarding electric vehicles in general and really push the change to electrified driving. These policies should address the issues with different charging providers and standardize the charging plugs and cables. Create incentive programs to support building of charging infrastructure in its member states by supporting to the local governments or offering direct support to the charging network companies.

7.2 Finland

In 2018 the total number of electric vehicles registered in Finland (including hybrid, PHEV and BEVs) was 5 708 EVs (Traficom, 2018) and to achieve the goal of 670 000 EVs by 2030, it would mean approximately 65 000 new electric vehicles registered per each year. While, the total registrations for new cars was 120 505 vehicles in 2018 (Traficom, 2018). The total registrations of new cars and car sales in Finland are not expected to grow much from recent years, which implicates that the electric vehicles need to acquire much higher percentage of the new car sales in the future.

This would mean about half of the new registered vehicles should be electric and since the development of new car sales in Finland is relatively slow, it seems unlikely that there will be 670 000 EVs by 2030.

As a conclusion this paper concludes that the goal of 670 000 electric vehicles in Finland by 2030 seems unlikely. At the current rate of development in the car market, there won’t be enough time to support the sales of electric vehicles to reach the goal, but there are many factors that can still affect this. In the long-term, popularity of electric vehicles in Finland will increase. It can be expected that the sales will speed up significantly when the price of EVs is decreased to be more competitive with the ICE vehicles or when better incentives are created to support purchasing of electric vehicles. At the moment, there is troubling trend in Finnish car market, as many are buying
second-hand diesel vehicles from abroad and the domestic sales in new vehicles have decreased. This means that people are not satisfied with the current state of car prices and taxation. Also, people are not sure when to buy new petrol or diesel vehicle if it will significantly drop in value in the next five to ten years. But at the same time the incentives to purchase electric vehicles are not efficient enough and people are waiting for a change. When the secondary market of electric vehicles increases in the future, it would make them more affordable to majority of drivers and increase further their popularity in Finland.

It can be expected that by 2030 the electric vehicles have developed technologically enough to have sufficient driving range, competitive pricing and charging infrastructure. By then EVs have established a strong position in the car market and many European car manufacturers have moved towards hybrid and electricity powered vehicles by stopping development of petrol and diesel engines. However, it can be expected that ICE cars have not disappeared from the market but have gradually decreased from the stock as they get older and more stricter emission rules are implemented in the member states. In country like Finland, it can be expected that petrol and diesel vehicles are going to be used for a long time because of their affordability in the second-hand market and long mileage capability. Until the sales of fossil fuels is prohibited, ICE vehicles are not truly disappeared from Finland. In central European countries it can be expected to happen faster, and electric vehicles are going to be adopted much faster as part of the daily passenger driving. Countries with developed electricity grid and charging infrastructure will have electric vehicles as default choice of passenger transportation in the cities sooner than those with undeveloped infrastructure. In rural areas the development will be much slower due to the long distances. However, there are exceptions where the electric vehicles have already gained huge success in popularity. In Norway the government is supporting heavily the purchasing of electric vehicles and therefore making their price more affordable and much more competitive. According to Helsingin Sanomat newspaper article: already half of the new vehicles sold in Norway were fully electric in 2018 (Helsingin Sanomat, 2019).

The outlook for electric vehicles is looking good and there seems to be increasing interest towards them. In my opinion to make electric vehicles more popular in Finland, it needs
the right conditions to succeed. This requires changes in taxation. Make EVs more affordable by offering tax benefits to those who purchase them and increase the fossil fuelled vehicles tax gradually over the years. Another condition is sufficient charging infrastructure. It is already good enough for most who live in capital region, but once the network covers more of Finland, there will be more people buying electric vehicles. The third conditions is that the EVs must have longer range than they do today, and once they can be driven 500+ kilometres, they will truly offer better value. Buying an EV is not cheap and to make the purchase justified economically, it needs these conditions to succeed. Many people care about the environment and want to reduce CO2 emissions in driving, but for most this won’t be good enough reason to purchase an EV. As the production of ICE vehicles is predicted to decreases over time, it will be interesting to see how the electric vehicles market develops in the future and what new changes there will be.

During the writing of this research paper, there were lot of new developments coming out from the automotive industry and many of them positive towards the change to electrified driving, such as announcements of new planned EV models, investments in the development of EVs and battery technology, battery size increasements and other events that could possible affected the supply chain of battery raw materials. This shows that the development is being very quick, and a lot can happen in even six months. But there are many events that can have even unexpected impact on the development of electric vehicles in European markets. Events such as disruptions in the battery materials production or new discoveries of key battery materials like lithium or cobalt, major political changes such as the USA – China trade war can ultimately have an impact on how the electric vehicle industry will develop in the future.

This research paper focuses on the topic from a local perspective in Finland but takes in consideration the larger perspective and the European Union’s role in development, by further discussing the issues in European level, because the decisions made in the EU level will ultimately affect Finland as well.
7.3 Suggestions for further research

Further research could be continued to explore the customer behaviour of new car buyers in Finland. This could help figuring out the readiness of Finnish people to purchase an electric vehicle and change their driving habits to more electrified and figure out what drives people towards EVs. Conducting a large-scale quantitative survey could be beneficial for the Finnish policy makers in order to create better and more efficient incentives and ways to increase electric vehicles popularity in Finland. Also, it would be interesting and relevant to continue investigating the global supply and demand of battery raw materials further, to establish deep understanding of the state of resources available for mass manufacturing of electric vehicles in the future. This thesis is limited to a quite primal information of broad and complicated topic, a topic which keeps developing all the time and therefore more research could be done in order to understand better the issues regarding mass production of electric vehicles, their technology and demand.
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