Electric Mobility in Europe for 2030-2040

Volkan Işık
volkan.isik.vi@gmail.com

Instituto Superior Técnico, Universidade de Lisboa, Portugal

December 2017

Abstract

Mobility has been very important in order to improve the civilization of the humankind in the past and its importance is increasing with the improvements in technology. It is one the crucial factors for the economic growth for the countries. 90% of the fuel used in transportation comes from the petroleum based products; therefore, the global greenhouse gas (GHG) emissions due to transportation is 23%. Transport sector is one of the main sectors which the GHG emissions should be decreased to reach the Paris Agreement goals. Electric vehicles (EV) is a very promising alternative to this task. With the combination of electric vehicles, car-sharing, and self-driving vehicles, the amount of car ownership could be decreased by 80% in the future. This would result a tremendous decrease in the GHG emissions as well as decrease in air pollution and congestion in the big cities. As EV penetration increases, power generation sector and the mobility sector would need to work together to balance the increase electricity demand due to EV charging. Smart charging and vehicle-to-grid (V2G) technologies could increase the penetration of renewables into the grid because EVs could be charged with renewable electricity. As one of the biggest utility company in the world, Iberdrola could place importance on electric mobility in the future. Their high share of renewable electricity production will help to charge EVs with 100% renewable electricity. Furthermore, they could provide zero emission car-sharing service to the customers in order to reach the company goals and Paris Agreement goals for a sustainable future.

Keywords: Mobility, Greenhouse Gas Emissions, Electric Vehicles, Car-sharing, Self-driving Vehicles

1. Introduction

Fossil fuels have good energy density and they are used to produce electricity in the modern world; however, as a result of this action, they emit a huge amount of CO_2 and the greenhouse gases to the atmosphere. The increase of the concentration of the greenhouse gases in the atmosphere causes an increase of the temperature of the earth since these gases (CO_2, methane, soot and other pollutants) act like a blanket; keeping heat radiation comes from the sun in the world. The temperature of the earth is constantly increasing. This change in the temperature of the earth is modifying the climate system including lands, oceans and the glaciers [1, 2]. GHG emissions due to transportation are substantially high; since transportation has a high influence on the society. It plays a crucial role in the economic growth of the country due to the fact that it helps to the other sectors to grow more [3]. According to the Environmental Protection Agency (EPA), 27% of the GHG emissions in U.S occurred due to transportation in 2015 [4].

The European Commission has the target of reducing GHG emissions in transport by 60% until 2050 as compared to emission level in 1990. It can be said that the GHG emission levels from transportation were increased approximately 20% since 1990. That makes transport sector only major economic sector in EU where GHG emissions have risen until now. It is estimated that there will be a significant growth in transportation sector until 2050. Current estimates show that climate policies in EU countries would decrease the GHG emissions in transport in 2050 by 8% below the 2010 level mainly due to the technological development in the car industry. Nevertheless, according to this estimation, the GHG emission level in 2050 would still be 15% higher than the 1990 level [5].

Apart from climate change, the impact of transportation on air pollution, noise pollution, and habitat fragmentation is substantial. High volumes of traffic cause important problems in most of the big cities. Transport is the main contributor to dangerous noise levels especially in the urban areas. Moreover, it causes negative effects on ecosystem and biodiversity [5].

When all these negative sides of transporta-

tion are considered, significant efforts and crucial changes should be done in the transport sector to accomplish the targets which have been taken by European Commission. There are several ways to decrease the GHG emission; amongst these alternatives, increase the number of electric cars in the transportation sector and use renewable sources for charging applications is one of the most favorable ones.

Electric vehicles can either be pure electric or with hybrid technology such as internal combustion engine with an electric motor. They can be divided into 6 different group which are Light Electric Vehicles (LEVs), Industrial Forklifts, Fuel Cell Electric Vehicles (FCEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs). The focus will be on the BEVs, HEVs, and PHEVs in the report.

1.1. Thesis Outline

The EV market outlook and the future projections about this market can be found in chapter 2. Furthermore, this section includes the information about what are the other the utility companies doing in electric mobility. Chapter 3 investigates the car sharing concept; there are some business models for car sharing. In addition to the car sharing, the reader can find information about self-driving vehicles. In the last section of this part, there are some future possible projections with the combination of car sharing and self-driving vehicles applied to EVs. In chapter 4, literature research on the charger types and the impact of EV charging on the grid is investigated. Moreover, vehicle to grid, smart charging, and fast charging concepts are also investigated in detail. Chapter 5 gives information about what Iberdrola is doing on electric mobility field. Due to the detailed market research done in the previous sections, a business model is proposed to the company which can be applied in the future in order to increase the penetration of electric mobility and to increase the companys value on *Sustainable Mobility* and *Green and Sustainable Future*.

2. EV Market Outlook

The total number of electric cars driven on the road has passed 2 million unit threshold; however, the market share of EVs globally is still very low 0.2% [6]. In 2016, the number of electric cars sold worldwide reached a record number with 750,000; around 40% of the electric cars were sold in China and they have the largest electric vehicle stock in the world as a result of this [7]. The EV market in China is big due to the government policies. For instance, it was announced that there will be no more approval for opening of a new ICE vehicle manufacturing facility. Moreover, the financial and non-financial subsidies for EV has a huge importance in the country [8].

The number of battery electric vehicles sold in Europe and number of HEV sold in Europe has increased around 30% and 61%, respectively [9]. When the market share of EVs in each country is investigated, it can be seen that the Norway has the highest ratio with a percentage of 29%. Norway has this highest deployment rate of EVs due to the policies of its government. For example, there is no acquisition tax for the electric cars; moreover, 25% of value-added tax (VAT) is exempted at the purchase of BEVs. In addition to these, there are also high variety of waivers applied to the EVs; such as road tolls and ferries [7]. The Netherlands are pursuing another policy for the taxation. In the country, there is a differentiated CO_2 based taxation which increases gradually until 2020. In 2016, every car owner was obliged to pay a tax according to the km that they cover if they are using conventional vehicle or hybrid vehicle; €6 per g CO_2/km. BEV owners do not need to pay for this tax due to the zero emission drive.

2.1. Future Projections for Electric Mobility

Battery is the important part of an electric vehicle and big portion of the manufacturing cost of EV is coming from the cost. Since the battery costs are currently high, it results in a high manufacturing cost for the electric vehicles [10]. In some sources, it is estimated that there will be a cost parity between ICE and EV in a couple of years in Europe. This projection is due to the unexpected decrease in the battery costs; that is, the battery cost has fallen faster than it was predicted eight years ago [11]. It is stated in the White Paper for the Future of Mobility prepared by Bloomberg New Energy Finance that the cost of the batteries will go down until $100/kWh in this decade [3]. Apart from these optimistic projections, it is estimated in IEAs report on Global Electric Vehicle Outlook that ICE and EV are going to be fully competitive in Europe by 2030 [7]. Moreover, in the paper of Battery Technology Charges Ahead prepared by McKinsey & Company, it is estimated that the battery prices will go until $160/kWh by 2025 [12]. Tony Seba mentioned the same type of projections in his book 'Clean Disruption of Energy and Transportation: How Silicon Valley Will Make Oil, Nuclear, Natural Gas, Coal, Electric Utilities and Conventional Cars Obsolete by 2030'; the price will go below $100/kWh around 2023 [13]. The price limit of $100/kWh is very important for the manufacturing cost of electric vehicles. An EV with a range of 200 miles (322 km) needs 50 kWh battery pack on board [13]. If it is assumed that the battery pack price is $100/kWh, that means the cost of the battery pack for a 200-mile range EV will be $5,000; that is, the EV will

become fully cost compatible with an ICE vehicle without incentives.

According to the projections made by BP, there will be 100 million electric vehicles on the road by 2035 [14]. On the other hand, IEA projects in its report Global EV Outlook 2017 that there will be between 9 million and 20 million electric cars on the roads by 2020, and between 40 million and 70 million electric cars by 2025 [7].

2.2. Future Plans of Utilities

Large scale of electricity production from renewable sources is forcing the conventional grid to change, and it affects the industry substantially. With more penetration of renewables into the electricity market, the wholesale electricity market price is forced to go down. As a result of this phenomenon, the revenue of utilities decreases; because the utilities start losing money from the electricity production. According to the financial data of 2013, the German utility company RWE has lost more than $3.8 billion in 2012 due to the sliding wholesale electricity prices. For Swedish utility company Vattenfall, the fate was similar also for the year 2012; they have lost $2.3 billion [15]. These numbers show that the disruption of traditional, centralized power production is a substantial threat for the power utility companies. Therefore, some changes need to be done for the business models of the utilities [16].

When conventional way of electricity production is disrupted, some new areas will be created for the utility companies; one of the most important area is the electric mobility. In the upcoming section, some information about the activities of competitors of Iberdrola on electric mobility field can be found.

RWE / innogy

As the second biggest electricity producer in Germany, they offer smart charging infrastructure, IT services and intelligent e-mobility solutions for cities, and private electric car users. There is also extensive research on the integration of electric vehicles into the energy system in order improve the usage of renewables in the grid. With their partners, RWE has developed standards for charging plugs and data which flows between the electric vehicle and the charging station [17].

In 2015, German based discount supermarket Aldi and RWE established a public DC charging station in one of the Aldi stores in Dusseldorf. The electricity taken from the charger is free and it is provided via the solar panels on top of the Aldi building [18].

Apart from the charging infrastructure, RWE and Renault have a partnership to produce a residential wallbox RWE eBox and RWE eBox Smart. RWE eBox is produced for the residential use. It helps to charge the electric vehicle 5 times faster than the normal power socket [19]. RWE eBox Smart is upgraded version of the regular eBox. It can charge the electric vehicle 10 times faster than the conventional power socket [20].

innogy

Innogy is an energy company which is a subsidiary of RWE (76.8% of the shares belongs to RWE). It was created on 1st April 2016 in order to split renewable, retail and the network business of RWE. A new unit which is called eMobility has been launched in January 2017. This new business unit pools all electric mobility activities in one roof. In Europe, innogy already operates one of the largest charging networks with 5,300 charging points in more than 30 countries [21].

RWE is one of the founders of the project HUBJECT in 2012; and now Innogy is one of the main partners of the project with BMW Group, Daimler, Bosch, EnBW, Siemens and Volkswagen Group. The main goal of the project is to create an eRoaming platform in Europe; that is, EV users can charge their vehicles in any kind of charging infrastructure in anywhere in the world [22].

Like RWEs eBox, Innogy also provides the same technology to the houses. People can mount the eBox in their homes in order to charge their electric cars 5-10 times faster than the normal power socket. Innogy has a new test product from its innovation hub; eCarSharing. In this pilot project, municipalities, companies and private individuals are offered electric vehicles which they can rent them through online platform [23].

EDF

French based utility company invests in different fields related to electric mobility; (i) design, installation and supervision of charging infrastructures of electric vehicles, (ii) rental and battery fleet management (buses and trucks), (iii) fleet management (companies and local authorities). Sodetrel, subsidiary company of EDF, is highly active in the first field. They are responsible for deployment, technical operation, and maintenance of the charging stations for the electric vehicles. They are also responsible for electric fleet management and onboard energy [24]. In December 2014, they have started a project called CORRI-DOOR. The aim of the project is to install 200 electric vehicle charging stations in France. The distance between two charging terminals is 80 kms and the drivers can charge their electric vehicles with 100% renewable electricity and with fast charging technology in 20 to 30 minutes [25]. EDF and Sodetrel have partnered with Renault, Nissan, BMW, and Volkswagen for the project [26].

Ombriwatt, a product from EDF ENR Solaire, aims to produce electricity by using solar panels and use that electricity for charging the electric vehicles.

It is a parking shelter which protects the vehicle from the sun or bad weathers; and, the roof of the shelter is equipped with PV panels [27].

In 2015, all the buses operate in Paris were ICE vehicle. However, with a 3-year agreement signed in 2014 between Paris Transit Authority and EDF, 4,500 buses of greater Paris network will be clean by 2025; 80% will operate with electricity and 20% will operate with biogas. As a result of this transition, the carbon footprint of Paris Transit Authority will be decreased by 50% [28].

As a three-year pilot project, a new urban transportation model started to operate in 2014 in the city of Grenoble. According to the project, Toyotas ultra-compact electric vehicles are used for the public transportation. The first and the last miles are planned to be covered with these EVs. Moreover, with the help of a software or a smartphone application, customers can choose the best roots for themselves [29].

EDF started to a partnership with Forsee Power, highly respected and experienced company in the battery market. Through this partnership, both sides are aiming; (i) to involve in the development of new storage options and batteries for heavy electric vehicles, (ii) to perform different research around existing and future lithium battery performance, (iii) to increase the both companies public awareness in this field [30].

In order to be more active in the private customer market, EDF established Sowee which is a subsidiary aimed entirely the private market. Using Sowee, the customers are able to arrange their domestic electricity consumptions as well as the recharging of electric vehicles with the help of a Sowee device [31].

E.ON

According to the press release from E.ON, they announced to have a new strategic e-mobility unit. Their aim is to have the leading role in the European charging infrastructure market. The company has already been offering power wall solutions both private customers and businesses. Also, they are planning to secure the locations for charging stations and to increase the number charging infrastructure on the roads [32]. E.On wants to increase the number of fast charging stations. The goal is to implement as much fast charging stations as possible until 2020 with the major car manufacturers such as Daimler, BMW, Ford, and Volkswagen [33].

With its extensive knowledge and expertise on charging infrastructure, E.ON plans to help to its partners or customers to select the suitable charging points, operate the charging columns, provide suitable payment systems and manage the overall business [34].

In Denmark, E.ON and CLEVER, Denmark based e-Mobility service provider, have made a strategic partnership. Two sides have an experience in installing and operating EV infrastructure in Northern Europe [35]. E.ON has 2,500 charging points in Denmark [32]. The important goal of this partnership is to implement several hundred ultra-fast charging stations for EVs throughout main European roads with a distance 120-180 kms between chargers [35]. Moreover, E.ON has created a smartphone application which is called EasyPark in Denmark. With using this application, the customers (either have E.ON card or not) can find the available parking spot and the electric vehicle charging infrastructure from the phone [36].

E.ON provides to its private customers a card that can be used in 4,000 charging stations in Germany. Furthermore, with using smart phone application E.ON Drive, customers can find the nearest charging station and get instant information related to the charging status [37].

In December 2016, the company has announced the partnership with e-bike manufacturer Derby Cycle. E-bike manufacturer will share its experience with e-bike market and business models related with e-bikes [38].

ENEL

In Italy, the company currently has 2,650 recharging stations for electric vehicles, 850 of them is public and 1,800 of them is private. Customers, whether they are Enel Energia customers or not, can use the Enel public chargers with the smartphone application which is called E-go Ricarica. The application gives chance to the customers to charge their EV at the service station visible on the application [39].

Enel and the ALD Automotive Italia have announced their partnership. Customers will be offered solutions according to their needs. For instance, with using E-Go Ricaricar, customers are able to choose the model of the electric car that they want to use. They need to pay only for the kms they have covered by using the smartphone application. Another tailored solution for the customers is E-Go Noleggio a Lungo Termine, which offers to the customers to rent an electric vehicle for a long-term. Apart from these two solutions, the collaboration of two companies offers to their customers E-Go Car Sharing. With using E-Go Car Sharing, customers have a chance to rent a zero emission cars [39].

Enel and Nissan has been working together since June 2016 and they have launched together E-Go All Inclusive in November. It gives opportunity to the customers to buy a package with a fixed monthly fee; Nissan LEAF with 30 kWh battery pack, power box with installation and E-Go app that helps customers to find the closest available charging station and charge their EVs [40].

The alliances with Nissan and BYD was made in June 2016. Enel aims to be one of the key players in Europe on electric mobility and the energy storage with the help of these alliances [41].

In order to develop the charging infrastructure throughout the main European motorways, Enel is working on a project called EVA+ (Electric Vehicles Arteries) with some automobile manufacturers such as Nissan, Renault, BMW, Volkswagen and Austrian utility Verbund. By the end of 2019, 180 fast charging points are aimed to be constructed [41, 42].

Enel, Nissan, and IIT (Italian Institute of Technology) have announced their collaboration to work on V2G in Italy. A pilot project on corporate car sharing has started at IIT's headquarters in Genoa. Enel provides 2 charging infrastructures and Nissan provides 2 Nissan Leaf and an app management platform which is called Glide to the IIT [43].

ENGIE

The name of their green mobility program is Better Mobility TODAY which is a part of TODAY initiative. Engie aims to improve air quality, to reduce noise pollution, to reduce congestion in the cities and to optimize transit network [44].

In order to spread the green mobility throughout Europe, Engie created a mobility program called Better Mobility TODAY. Car-sharing, electric bus charging infrastructure, electric charging networks, demand-response aggregation, smart charging, and renewable electricity for vehicles are the important topics for electric mobility for the company [45].

During the past years they have already installed more than 5,000 charging points throughout Europe. The company is making the design of the charging points and the coverage of the geographical area. After the design, installations and commission is done. Maintenance service is given 24/7 to the customers about the charging point. Furthermore, electricity used for chargers are produced from local renewable sources [46]. Engie provides these service with the help of EV Box, a company founded in 2010 in Netherlands. Engie made the acquisition of EV Box. Both Engie and EV Box have same vision on electric mobility; and, with this acquisition Engie aims to combine its globally well-known name, and energy capacities with EV Boxs high technology EV chargers [47]. Engie and EV Box have aimed to construct 4,000 new charging points for electric cars in Netherlands; 1,800 of 4,000 charging stations will be in Rotterdam [48]. In addition to the EV charging stations network, Engie also provides smart charging solutions to the customers [49].

They offer a professional car-sharing service to the municipalities and to the companies which want to establish a car-sharing service to its employees. The car-sharing service that they offer includes; a booking application for company cars, installation and commissioning of charging stations, power supply to the charging stations with electricity produced from renewables, maintenance service, renting of electric cars [50].

Recently, Engie has announced that they invest in Gogoros Electric Smartscooters and energy network technologies. The Gogoros Smartscooter is an innovative technology which was found in 2011 in Taiwan. The scooters are special because they have 2 swappable batteries. The innovative battery swapping system allows users to see the state of charge of battery via smartphone application and also allows them to change the batteries by using the application [51].

Vattenfall

Vattenfall is involving of installation of charging stations throughout Europe. They have already installed fast-charging stations in Stockholm and Uppsala. Moreover, in Netherlands and Germany they operate more than 1,000 public electric vehicle charging stations mainly in Amsterdam, Hamburg and Berlin [52]. Nuon, a utility company which belongs to the Vattenfall group, and its partner Heijmans have announced that they won a contract for the south part of Netherlands. They will install and operate around public 2,500 charging points in 65 different municipalities. The installations has already started in March and it is planned to be done until 2018 [53].

With InCharge project, Vattenfall aims to build charging network which allows its customers to access thousands of charging points in Sweden, Germany and Netherlands. The EV owners are able to charge their cars via using InCharge smartphone application, charging card or RFID-tag [54].

According to the press release in March 2017, Vattenfall invests to the project company Northvolt in order to build Europes largest lithium-ion battery production factory in Sweden. Construction will start in the second half of 2018 and it is planned to start production at the end of 2020 [55].

The company has announced to replace all of its car fleet in Sweden, Netherlands and Germany with either electric or hybrid cars. More than 3,500 passenger vehicles and light commercial vehicles, 1,700 vehicles in Sweden, 1,100 vehicles in Germany and 750 in Netherlands, are going to be replaced with EVs in 5 years. This announcement shows that Vattenfall supports the movement towards zero emission mobility [56].

EDP

EDP offers some solutions about electric mobility to its customers. One of them is the EV charging stations. EDP makes the installation and the maintenance of the charging stations [57]. EDP is also a

partner company of Mobi.E, a Portuguese program for electric mobility. The Mobi.E program provides to its customers to charge their electric cars with the public charging infrastructures throughout Portugal [58].

3. Car-sharing and Self-driving Vehicles

Importance of mobility for the big cities is substantial. Every day, people go to their work or school or the places that they need to go with vehicles unless the distances are short. Furthermore, mobility is important for transferring of food and essential goods, and the transportation of waste. The world's population is expected to increase up to 9.1 billion people by 2040, and 60% of the world's population is going to live in the big cities by 2030. Increase of population living in the cities will bring some problems; such as traffic density, energy consumption, pollution, and congestion. As the number of people in the cities increases, the mobility will become more important [3]. Combination of three important technologies could help to prevent these problems in the future; electrification of road transport, shared mobility and autonomous vehicles.

3.1. Car-sharing

Success of Uber

Although ride-hailing (i.e. Uber, Lyft) and car-sharing target the same customer segment; that is, these two type of services are rival to each other, the success of Uber shows really good that there is a change in people's behaviours about car ownership. In other words, people's behaviors towards the mode of transportation are changing. Application-based ride-hailing, on-demand servicing (i.e. Uber, Lyft, Juno) had 50,381 vehicles in New York City and in 2016 they were providing service to 500,000 passengers per day [59].

Advantages of Car-sharing

Car-sharing concept has not only environmental benefits but also provides people social and economic benefits. Car-sharing helps to decrease the number of car ownership. Considering a study performed in Vienna last year, around 5 private vehicles can be replaced by one car-sharing vehicle. Due to this reduction in the number of car ownership, 44 million private kilometers with vehicles and 7 metric tons of CO_2 emission is prevented [60]. The GHG emissions and the air pollutant substances can be decreased tremendously with car-sharing. Furthermore, with the car-sharing, users do not need to pay for the insurances, taxes, and fuel; thus, people can save money [61].

Another benefit of car-sharing is from the social perspective. It can be said that car-sharing could be defined as the more responsible version hitch-hiking in todays world [62].

Types of Car-sharing

Although car-sharing is one type of car rental, they are quite different from each other. Usually, customers rent the car for daily purposes for the car rentals. The fuel cost and the insurance cost are not included in the overall cost; therefore, customers need to pay additional money for these costs. Furthermore, customers need to make a new contract each time they rent the car. With car-sharing, the rates are mostly minute based. Short-term access, gives customers the huge amount of flexibility. Most of the car-sharing systems work with membership based. Customers need to register to the website of the car-sharing company. They can have the vehicle via the smartphone application or from the website 10-15 minutes before the pick-up. Unlike the car rentals, the insurance and the cost of fuel are included in the price [5].

There are different types of car-sharing. In station based car sharing, the customers need to pick up and return the cars to the stations. There are some car parks or designated areas where the customers can pick up and leave the vehicles. In free-floating car-sharing model, customers can pick up and leave the vehicles anywhere they want in the city. This provides users huge flexibility. In peer-to-peer car-sharing, people who have a vehicle can rent their vehicles via smartphone application [63, 64].

3.2. Self-driving Vehicles

Self-driving, also called autonomous driving, technology is improving rapidly. The term autonomous vehicle does not only mean a single vehicle with a set of technological capabilities. It means rather several vehicles interact with each other on the road and using an online network in order to share the data globally and learn [65].

There are 5 different types of the level of autonomy. Level 0 means that there is no automation in the vehicle. At all times the driver is in charge of the control of the car. Level 1 can be classified as one function-specific automated. In this type of vehicle, only one type of function is automated at the time. If multiple functions are operated at the same moment, they operate independently from each other without any communication (i.e. automatic assisted breaking). Level 2 is called two functions automated and combined. In this level, at least two primary control functions work autonomously and together. This level of automation allows driver to leave the control to the vehicle. The driver can leave the steering wheel to the car and take the foot off the gas and brake. The vehicle can achieve to drive by itself without any driver input by combining different automated functions (i.e. adaptive cruise control with combination or lane management). Level 3 is limited self-driving automation. With this level of automa-

tion, the driver can leave the critical functions to the vehicle. In other words, the driver can spend his or her time by doing some other activities in the car without paying attention to the drive. The driver is only expected to be available from time to time for occasional controls; however, they have a sufficient time for taking the control of the car (i.e. Google's self-driving car). Level 4 is the full self-driving automation. This type of vehicles can drive themselves without needing any driver. The vehicles can monitor the road conditions for entire trip and carry out driving with safely with the help of ultrasonic sensors and cameras; this type of automation is not commercially available yet [13].

Advantages of Self-driving Vehicles

Autonomous driving has lots of superiority in driving against human drivers. First of all, they have 360 degrees of vision range and the computers cannot be distracted like human drivers. Due to the sensors and the camera, they can even see in the night and they do not have a sleep pattern; thus, they can operate 24 hours of the day without any accidents. Self-driving car technology is not perfect yet; however, they are still better than most of the human drivers. One of the most important features of autonomous cars is the ability to learn from the mistakes. Human being tends to make the same mistake over and over again without learning from their mistakes. Unlike the human drivers, autonomous cars can learn from data that all other autonomous cars are collecting due to the online network they have between each other. Car accidents can be prevented with autonomous driving and more lives can be saved [13].

The intelligent vehicles can reduce the space needed substantially. An automated vehicle needs 25% less space for changing the lane or overtaking a car. Moreover, with adaptive cruise control technology, the capacity of highways can be improved around 40%. In other words, the self-driving cars could drive closer to each other at high speeds due to the vehicle to vehicle communication on the highways; thus, they increase highway capacity by 3.7 times and they could help vehicles to save fuel (10-15% fuel saving) due to less wind resistance. Furthermore, the self-driving cars can park themselves. This feature allows them to decrease space between cars while parking and save 15% of the parking space [13].

3.3. Mobility as a Service

Nowadays, people own cars just because they need mobility-on-demand; that is, they want to be free and want to travel whenever they want and wherever they want. Most of the people don't really want to own a car since it is costly. Combination of EVs and self-driving vehicles will most likely to disrupt the conventional transportation and will create on-demand mobility service. With mobility as a service, people will travel around cheaper with the same level of flexibility and comfort. Since this service will be cheaper than the cost of car ownership, most of the people will stop owning a car and use this service. As a result, the number of cars on the roads will decrease tremendously [13].

4. EV Charging

4.1. Impact of EV Charging on the Grid

Electric vehicles are one of the best solutions to decrease the greenhouse gas emissions and air pollution in the cities due to transportation. However, renewable electricity should be used in the cars in order to have overall lowest carbon footprint. If the electricity used for charging is produced from coal, the overall carbon footprint of EVs are worse than the overall carbon footprint of ICE vehicle works with gasoline [5].

As the number of EVs on the road increases, the boundaries between the transportation and the power generation will disappear since EV charging will have some impact on the grid. These two sectors should work together in order to balance the grid. Smart charging and vehicle to grid (V2G) technologies will be more important in the future [66].

Smart Charging

Smart charging, also called managed charging, is a way of charging the EVs in contrast to uncontrolled and user-driven charging patterns. The charging patterns and when the EVs are being charged strongly affects the grid. With the help of smart charging, the negative effects of EV charging on local grids can be eliminated. Also it eliminates more GHG emissions [66].

If EVs are connected to the grid not only at homes but also at the workplaces during the day, smart charging can be applied to more vehicles; thus, a positive impact of smart charging on the grid can be seen. The willingness of EV owners to use smart charging approach is very important. EV owners can be incentivized by offering them cheap charging options or some discount through their electricity bills [7].

Vehicle to Grid (V2G)

With the increasing penetration of EVs in the future car market, their batteries could be used as a grid source in the future. V2G creates opportunities to generate cleaner power, to have a lower energy cost both for the EV owners and utility companies, and to achieve greater stability in the grid. An average car stays parked 23 hours of one day [67]. Moreover, an average charging time of the EVs is around 7-8 hours with slow chargers. When an EV is considered to be plugged into the grid 96% of its time, this creates a huge opportunity for using EVs

as a grid source. EVs could back up the grid when it is needed and they can help for the peak hours shaving by supplying their renewable electricity which is stored in their battery. Furthermore, one of the goals of V2G application is to increase the penetration of renewable energy sources in the grid. The cost of solar PV and wind turbines are decreasing and renewable energy production in the future is expected to increase due to the low emission energy policies. Due to the fluctuating nature of solar and wind, penetration of these renewable sources will create instabilities in the grid [68]. V2G has a potential to decrease these instabilities; thus, it could increase the penetration of renewables [67]. Like smart charging, V2G has the same problems about the willingness of the EV user. Since the users need to sacrifice some of their freedom, they need to be incentivized.

4.2. Electric Vehicle Supply Equipment (EVSE)

Availability of charging infrastructure is one of the key factors in order to overcome range anxiety of some of the drivers for the EVs. The electric vehicle uptake will increase with more charging stations in the cities and on the main roads. This is more like a chicken-and-egg problem since more EV brings more charging infrastructure; likewise, more charging infrastructure will increase the adoption of EV in the vehicle market. There are 3 different types of charging points; private/domestic charging points, semi-public charging points, and public charging points [69].

5. Discussion and Proposals

5.1. Electric Mobility from Iberdrolas Perspective

Likewise its competitors, Iberdrola gives importance on sustainability by decreasing the GHG emissions and increasing the use of renewables in the electricity generation. According to the Dow Jones Sustainability index, Iberdrola decreased its GHG emissions by 31% in last five years and by 75% since 2000 [70]. Moreover, in 2015, the share of renewable energy was higher for Iberdrola when it is compared with its competitors [71]. In order to promote green mobility, Iberdrola came up with a sustainable mobility plan, and 23 initiatives. According to this plan, they incentivize their employees to use electric vehicles [72]. Furthermore, Iberdrola offers two different charging options to its EV user-customers; Green Charge, and Smart Green Charging [73]. An agreement between BMW and Iberdrola allows to the utility company to use BMW i3 cars in their car-sharing service which they provide to its employees [74].

5.2. Proposals on Possible Future Business Areas for Iberdrola

Car-sharing Service Provided by Iberdrola

It is projected that around 35 million users will drive 1.5 billion minutes annually by 2021 with car-sharing. Furthermore, this will bring a revenue of €4.7 billion. Europe will be the biggest market in car-sharing and it is expected to have revenues around €2.1 billion [61].

After the detail research done on the prospective future market in the mobility services, it can be said that it would be a good idea to involve in electric mobility programs as one of the biggest utility company in the world. According to my opinion, car-sharing with EVs would have benefits not only for increasing the penetration of renewables for Iberdrola but also for giving chance to them to exist in different potential future markets. With having EVs in their car fleet, they could use their batteries as a source for the grid when these cars are not rented by the customers (smart charging or V2G). For example, with the V2G application, Iberdrola can use that electricity in the car batteries when it is needed in order to decrease the expenses of the company during the peak times. The optimization between the charging and renting the car can be done easily. My proposal would be establishing a car-sharing service in Madrid since it is a very good candidate to start this service. It can be seen from the success of ride-hailing companies (Uber, Cabify) and some car-sharing companies (car2go, Emov) in Madrid that people in the city are eager to use these kind of services due to the congestion and parking problems mainly in the city center.

A smartphone application can combine the car-sharing service, EV charging service for the EV owners, and smart charging and V2G services for the EV owners. Due to this combination in the smartphone app, Iberdrola could reach different type of customer segments by using only one platform which makes it easy also for the customers. Furthermore, with combining these services in one, EV owners could be incentivized to use the V2G or smart charging more.

6. Conclusions

The objectives of the thesis were investigate the future of electric mobility mainly in Europe for 2030 and 2040 and propose a different business model according to these new e-mobility trends to the utility company Iberdrola. In order to reach the goals, detailed literature research was done on the following topics, (i) EV market outlook and future projections on the market, (ii) self-driving vehicle technology, (iii) car-sharing applied to EVs, (iv) vehicle to grid (V2G) applications, and (v) fast charging. Furthermore, actions of competitors were investigated in order to obtain information about the possible future business models. With the help of these extensive research done by the author, an electric

car-sharing business model was proposed for Iberdrola. The business model will help Iberdrola to involve in a new emerging market for the future. The value proposition of the model is flexible, environmental friendly (zero emission) and economic mobility service for the customers. In addition to renting the vehicles to the customers, owning an EV fleet and using the smart charging and V2G technologies with this EV fleet would help Iberdrola to manage their power production. For instance, Iberdrola could decrease its operation cost at the peak times by using V2G technology from its EV fleet as well as the V2G service that they provide to EV owners. In my opinion, a service of electric car-sharing to its customers as well as EV charging service, would help Iberdrola to be more active in this field to reach the company goals; decrease the GHG emissions and have a sustainable mobility. Furthermore, Iberdrola can use the advantage of disappearing the boundaries between mobility sector and the power generation sector by providing the electric car-sharing service.

Acknowledgements

The author would like to thank InnoEnergy for providing the scholarship for the M.Sc. ENTECH program and giving the chance to have double degree from both universities KIT and IST. Furthermore, the author is grateful to be able to do the research and write the master thesis with Iberdrola. My supervisors in IST and Iberdrola helped a lot while working on the topic.

References

[1] A. MacMillan, "Global Warming 101," 2016. [Online]. Available: https://www.nrdc.org/stories/global-warming-101

[2] M. Denchak, "Are the Effects of Global Warming Really that Bad?" 2016. [Online]. Available: https://www.nrdc.org/stories/are-effects-global-warming-really-bad

[3] C. McKerracher, S. Knupfer, I. Orlandi, M. Wilshire, S. Ramanathan, J. T. Nijssen, E. Hannon, and S. Ramkumar, "An Integrated Perspective on the Future Mobility," *Bloomberg New Energy Finance*, 2016.

[4] United States Environmental protection Agency (EPA), "Sources of Greenhouse Gas Emissions," 2017. [Online]. Available: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[5] "Transitions towards a more sustainable mobility system," European Environment Agency, Tech. Rep. 34, 2016.

[6] K. Fehrenbacher, "Electric Cars Hit the 2 Million Threshold Worldwide," 2017. [Online]. Available: https://www.greentechmedia.com/articles/read/electric-cars-hit-the-2-million-milestone-across-the-globe#gs.XERvkOY

[7] IEA, "Global EV Outlook 2017 Two million and counting," International Energy Agency, Tech. Rep., 2017.

[8] EV Volumes, "The Electric Vehicle World Sales Data Base." [Online]. Available: http://www.ev-volumes.com/country/china/

[9] H. Kesteloo, "Renault Zoe leads 49% sales jump in EV sales in Europe during first quarter 2017," 2017. [Online]. Available: https://electrek.co/2017/05/22/renault-zoe-leads-european-electric-vehicle-sales/

[10] S. M. Knupfer, R. Hensley, P. Hertzke, P. Schaufuss, N. Laverty, and N. Kramer, "Electrifying insights: How automakers can drive electrified vehicle sales and profitability," McKinsey & Company, Tech. Rep. January, 2017.

[11] J. Voelcker, "UBS study predicts electric-car cost parity in Europe could arrive by 2018," 2017. [Online]. Available: http://www.greencarreports.com/news/1110619_ubs-study-predicts-electric-car-cost-parity-in-europe-in-2018

[12] R. Hensley, J. Newman, and M. Rogers, "Battery technology charges ahead," 2012. [Online]. Available: https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/battery-technology-charges-ahead#0

[13] T. Seba, *Clean Disruption of Energy and Transportation: How Silicon Valley Will Make Oil, Nuclear, Natural Gas, Coal, Electric Utilities and Conventional Cars Obsolete by 2030*, 2014.

[14] BP Global, "The impact of electric cars on oil demand." [Online]. Available: https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/electric-cars-and-oil-demand.html

[15] S. Lacey, "This Is What the Utility Death Spiral Looks Like," 2014. [Online]. Available: https://www.greentechmedia.com/articles/read/this-is-what-the-utility-death-spiral-looks-like#gs._sdBYe0

[16] S. Rogers, M. V. Bechtolsheim, N. White, D. Borràs, R. Francis, and K. Ingham, "Radical Change for European Power Utilities," Tech. Rep., 2014.

[17] "RWE offers charging solutions for sustainable mobility." [Online]. Available: https://www.rwe-mobility.com/web/cms/en/2113790/emobility/about-rwe-emobility/

[18] C. Morris, "German supermarket chain installs solar-powered DC charging stations," 2015. [Online]. Available: http://electricmobility.efacec.com/wp-content/uploads/2015/07/chargedevs.com_newswire_german-supermarket-chain-install_Aldi.pdf

[19] "RWE eBOX." [Online]. Available: https://www.rwe-mobility.com/web/cms/en/1222606/products-services/emobility-produkte/rwe-ebox/

[20] "RWE eBOX SMART." [Online]. Available: https://www.rwe-mobility.com/web/cms/en/1227806/products-services/emobility-produkte/rwe-ebox-smart/

[21] Innogy, "Innogy drives forward expansion of electric mobility," 2016. [Online]. Available: https://news.innogy.com/innogy-drives-forward-expansion-of-electric-mobility/

[22] HUBJECT, "The eRoaming platform for customer-friendly charging of electric vehicles." [Online]. Available: https://www.hubject.com/en/

[23] Innogy, "innogy eCarSharing." [Online]. Available: https://ecarsharing.innogy.com/ecarsharing/vorteile/

[24] EDF, "2016 Facts & Figures," Tech. Rep., 2017. [Online]. Available: https://www.edf.fr/sites/default/files/contrib/groupe-edf/espaces-dedies/espace-finance-en/financial-information/publications/facts-figures/facts-and-figures-2016-en.pdf

[25] "Sodetrel." [Online]. Available: https://www.sodetrel.fr/

[26] "A 200 station network." [Online]. Available: https://www.edf.fr/en/the-edf-group/world-s-largest-power-company/strategy/edf-in-europe/a-200-station-network

[27] "Ombriwatt," EDF, Tech. Rep. [Online]. Available: https://www.edf.fr/sites/default/files/contrib/groupe-edf/premier-electricien-mondial/cop21/solutions/pdf/cop21-solutions_ombriwatt_va.pdf

[28] "A research partnership with the RATP," EDF, Tech. Rep., 2014. [Online]. Available: https://one.edf.fr/sites/default/files/contrib/groupe-edf/premier-electricien-mondial/cop21/solutions/pdf/cop21-solutions_bus2025_va.pdf

[29] Toyota Global Newsroom, "Cité lib by Ha:mo", a New Type of Urban Mobility Based on Ultra-Compact Electric Vehicles Connected to Public Transport, Launches in Grenoble, France," 2014. [Online]. Available: http://newsroom.toyota.co.jp/en/detail/3962091

[30] "Batteries for heavy electric vehicles," Tech. Rep. [Online]. Available: https://www.edf.fr/sites/default/files/contrib/groupe-edf/premier-electricien-mondial/cop21/solutions/pdf/cop21-solutions_forsee_va.pdf

[31] F. Jacobs, "Being an energy specialist gives us credibility in electric mobility," 2017. [Online]. Available: https://www.fleeteurope.com/en/interviews/being-energy-specialist-gives-us-credibility-electric-mobility

[32] E.ON, "E.ON shifts electro-mobility business into high gear," 2016. [Online]. Available: https://www.eon.com/en/about-us/media/press-release/2016/eon-shifts-electro-mobility-business-into-high-gear.html

[33] D. Pratt, "E.ON joins e-mobility drive with new business unit," 2016. [Online]. Available: https://www.cleanenergynews.co.uk/news/transport/e.on-joins-e-mobility-drive-with-new-business-unit

[34] "E.ON welcomes new e-mobility funding program," 2017. [Online]. Available: https://www.eon.com/en/about-us/media/press-release/2017/eon-welcomes-new-e-mobility-funding-program.html

[35] "E.ON and CLEVER cooperate on ultra-fast charging e-Mobility," 2017. [Online]. Available: https://www.eon.com/en/about-us/media/press-release/2017/eon-and-clever-cooperate-on-ultra-fast-charging-e-mobility.html

[36] "Park and charge with EasyPark," 2017. [Online]. Available: https://www.eon.dk/en_US/privat/charge-your-electric-car/easypark.html

[37] "Charge anywhere at more than 4,000 charging points in Germany." [Online]. Available: https://www.eon-drive.de/de/privatkunden/unterwegs.html

[38] "E.ON committed to electric mobility based on e-bikes," 2016. [Online]. Available: https://www.eon.com/en/about-us/media/press-release/2016/eon-committed-to-electric-mobility-based-on-e-bikes.html

[39] ENEL, "ENEL and ALD Automotive launch electric mobility offers for all needs," 2017. [Online]. Available: https://www.enel.com/en/media/press/d201705-enel-and-ald-automotive-launch-electric-mobility-offers-for-all-needs.html

[40] Autovista Group, "Enel Energia, Nissan Italia and IIT collaborate on the development of electric mobility," 2017. [Online]. Available: https://www.autovistagroup.com/news-and-insights/enel-energia-nissan-italia-and-iit-collaborate-development-electric-mobility

[41] "Seeding Energies Sustainability Report 2016," ENEL, Tech. Rep., 2016. [Online]. Available: https://www.enel.com/content/dam/enel-com/investors/2017/ENG_BDS2016_20170502_4WEB.pdf

[42] "E-mobility, Enel is a first mover," 2017. [Online]. Available: https://www.enel.com/en/media/news/d201706-e-mobility-enel-is-a-first-mover.html

[43] "Enel Energia, Nissan Italia and IIT join forces for the development of electric mobility," 2017. [Online]. Available: https://www.enel.pe/en/media/news/d201705-enel-energia-nissan-italia-and-iit-join-forces-for-the-development-of-electric-mobility.html

[44] "Green Mobility." [Online]. Available: http://www.engie.com/en/businesses/mobility-today/

[45] "About TODAY by Engie." [Online]. Available: https://mobility.today.engie.com/en/about/

[46] "Electric charging station networks," Engie, Tech. Rep., 2017.

[47] "ENGIE acquires EV-Box, the largest European electric vehicle charging player," 2017. [Online]. Available: http://www.engie.com/en/journalists/press-releases/engie-acquires-ev-box/

[48] "ENGIE installs 4,000 charging points for electric cars in Rotterdam and The Hague," 2016. [Online]. Available: http://www.engie.com/en/journalists/press-releases/engie-installs-4000-charging-points-rotterdam/

[49] "Smart Charging," Engie, Tech. Rep., 2017.

[50] "Car Sharing," Engie, Tech. Rep., 2017.

[51] "ENGIE Expands Green Mobility initiatives by Investing in Gogoro's Electric Smartscooters and Energy Network technologies," 2017. [Online]. Available: http://www.engie.com/en/news/engie-investing-in-gogoro/

[52] Vattenfall, "E-Mobility," 2017. [Online]. Available: https://corporate.vattenfall.com/sustainability/consumption/e-mobility-electric-mobility/

[53] L. M. Kihlström, "NUON Installs another 2,500 charging points," 2017. [Online]. Available: http://news.vattenfall.com/en/article/nuon-installs-another-2500-charging-points

[54] "Vattenfall builds the InCharge charging network with partners," 2016. [Online]. Available: https://corporate.vattenfall.com/sustainability/incharge/

[55] "Vattenfall supports major battery production project in Sweden," 2017. [Online]. Available: https://corporate.vattenfall.com/press-and-media/press-releases/2017/vattenfall-supports-major-battery-production-project-in-sweden/

[56] "Vattenfall is switching its whole car fleet to electric vehicles," 2017. [Online]. Available: https://corporate.vattenfall.com/press-and-media/press-releases/2017/vattenfall-is-switching-its-whole-car-fleet-to-electric-vehicles/

[57] EDP, "Electric Mobility." [Online]. Available: https://energia.edp.pt/particulares/servicos/electric-mobility/edp-solutions/

[58] MOBI.E, "How can I charge my electric vehicle?" [Online]. Available: https://www.mobie.pt/how-electric-mobility

[59] "New Yorkers likely abandoning public transit for Uber," 2017. [Online]. Available: http://www.crainsnewyork.com/article/20170310/TRANSPORTATION/170319992/new-yorkers-likely-abandoning-public-transit-for-uber-lyft-gett-via

[60] DriveNow, "Examining the sustainable effect of carsharing : DriveNow takes stock for European Mobility Week Press release," DriveNow Press Release, Tech. Rep., 2016. [Online]. Available: https://content.drive-now.com/sites/default/files/2017-03/2016.09.15_DriveNow_European Mobility Week.pdf

[61] J. Bert, B. Collie, M. Gerrits, and G. Xu, "What ' s Ahead for Car Sharing ?" The Boston Consulting Group (BCG), Tech. Rep., 2016. [Online]. Available: https://www.bcgperspectives.com/content/articles/automotive-whats-ahead-car-sharing-new-mobility-its-impact-vehicle-sales/#chapter1

[62] The Eco Guide, "The many benefits of car-sharing and carpooling," 2015. [Online]. Available: https://theecoguide.org/many-benefits-car-sharing-and-carpooling

[63] "Car Sharing in Europe - Business Models , National Variations and Upcoming Disruptions," Monitor Deloitte, Tech. Rep., 2017.

[64] J. Polak, S. Le Vine, and A. Zolfaghari, "Carsharing: Evolution , Challenges and Opportunities," ACEA, Tech. Rep. September, 2014.

[65] X. Mosquet, T. Dauner, N. Lang, M. Rüßmann, A. Mei-Pochtler, R. Agrawal, and F. Schmieg, "Revolution in the Driver ' s Seat - The road to autonomous vehicles," The Boston Consulting Group (BCG), Tech. Rep., 2015. [Online]. Available: http://image-src.bcg.com/Images/BCG-Revolution-in-the-Drivers-Seat-Apr-2015_tcm9-64351.pdf

[66] P. Kasten, J. Bracker, M. Haller, and J. Purwanto, "Assessing the status of electrification of the road transport passenger vehicles and potential future implications for the environment and European energy system," Institute for Applied Ecology, Tech. Rep., 2016.

[67] B. Müller and G. Meyer, Eds., *Electric Vehicle Systems Architecture and Standardization Needs*. Springer.

[68] T. Seba and J. Arbib, "RethinkX: Disruption, Implications and Choices - Rethinking Transportation 2020-2030," Tech. Rep. May, 2017.

[69] EEA, "Electric vehicles in Europe," European Environment Agency, Tech. Rep. 20, 2016.

[70] Prospex Research, "Europe ' s Top Twenty Power Industry Players 2016," Prospex Research, Tech. Rep. June, 2016.

[71] "Social Contribution 2016," Iberdrola, Tech. Rep. February, 2017.

[72] "Iberdrola reaffirms its commitment to the electric vehicle." [Online]. Available: https://www.iberdrola.com/wcorp/gc/prod/en_US/sostenibilidad/semana_movilidad1.html

[73] "Iberdrola Green Charge." [Online]. Available: https://www.iberdrola.es/home/services/equipment/charging/basic-green-charging

[74] "Iberdrola and BMW launch corporate electric car sharing service," 2015. [Online]. Available: https://www.evwind.es/2015/02/12/iberdrola-and-bmw-launch-corporate-electric-car-sharing-service/50456