MASTER THESIS

Strengthening the charging infrastructure for promoting E-mobility in the Netherlands

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ABSTRACT

The national climate agreement was held at the Hague in 2019, with the aim of reducing greenhouse gas emission in the Netherlands by 49% in comparison to 1990 levels. It sets targets for several sectors, including mobility. The best way of reducing greenhouse gas emission is by transition to the electric vehicles from conventional vehicles. Targets are set at European level for transport and CO2 for 2030 and 2050. To reduce greenhouse gas emission to 20% by 2030 and 60% reduction target from growing transport and supporting mobility. By 2050 it aims to phase out all conventional cars by 2050. The ambition of 2030 corresponds to 1.9 million electric vehicles and electricity requirement of 7,000 GWh where 1.7 million charging stations are required. Still it is not clear how the charging infrastructure will develop to meet the charging demand for EVs and to reduce range anxiety by new technology to make electric vehicles driver to charge their vehicles in a limited time.

The main objective this research is to investigate the challenges and opportunities in terms of the technical performance and stakeholder involvement for strengthening the electric charging infrastructure for e-mobility in the Netherlands. The research data was gathered by the desk research. First, the current situation in the charging infrastructure is analyzed by technology, organizations involved and technical performance. Then, the expected technological innovations are discussed. Furthermore, the current policies and future policies are evaluated to stimulate charging infrastructure for uptake of EVs.

The results from the desk research displayed that, Li-ion battery is having high specific energy and high efficiency over a long time. DC fast charging helps in charging EV to 80% within 20 minutes but the number of fast charging in the Netherlands is still lagging. Combined charging system connector is suitable for high power fast charging of EVs. There are several organizations involved to stimulate charging infrastructure in the Netherlands. ElaadNL facilitates innovative projects and knowledge exchange between the companies to reduce cost of charging infrastructure. The market model ensures the freedom of choice, the government encourage small and medium scale industries to start a process by helping them to make it easier. Analyzing technological performance helps in understanding charging behavior to install a greater number of charging networks. Smart charging will be best suitable for the market in future because it can be controlled externally by app and can use sustainable energy. The government formulated policies to reduce the costs on energy, tax and given subsidies to promote sustainable mobility. The RVO monitors National Agenda Charging Infrastructure to implement policies related to charging infrastructure. The government will also provide financial and tax incentives for EVs to increase a number of EVs for promoting sustainable transport.

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AC: Alternating Current
BEV: Battery Electric Vehicles
BPM: Private vehicle and motorcycle tax
CE: Coulombic Efficiency
CNG: Compressed Natural Gas
CO2: Carbon dioxide
CPO: Charge Point Operator
DC: Direct Current
DSO: Distribution System Operator
EMP: E-Mobility Provider
EU: European union
EV: Electric vehicles
GHG: Greenhouse gases
ICE: Internal combustion engine
IHA: Inductive Self-Healing Asphalt
IPT: Inductive Power Transfer
KPI: Key Performance Indicators
LNG: Liquified Natural Gas
LPG: Liquid Petroleum Gas
MIA: Environment Investment Tax Scheme
MRA: Metropole Region Amsterdam
MRB: Motor vehicle tax
MSP: Mobility Service Provider
NGO: Non-Governmental Organization
NKL: National Knowledge Charging Infrastructure Platform
PHEV: Plug-in Hybrid Electric Vehicles
PI: Performance Indicators
PM: Particulate matter
RVO: Rijksdienst voor Ondernemend Nederland
SER: Social and Economic Council of the Netherlands
SOC: State of Charge
VNG: The Association of Netherlands Municipalities

1. INTRODUCTION

When the industrial revolution started, the dependent on fossil fuels increased for the energy production which caused greenhouse gases in turn climate change. To reduce these effects on environment, including European union many organizations came up with the Paris agreement on December 2015 where 195 countries decided to limit average temperature of the global under 2°C over pre-industrial levels and to curb temperature less than 1.5°C. The European Union also aims to reduce climate change by reducing the greenhouse gases to at least 40% by 2030 compared to 1990 *(European Commission, 2019).* The target had been set for transport and CO2 for the year 2030 and 2050 respectively. In the Transport White Paper, the targets are set in the area of transport which shows directions for future transport and traffic policy. The main objectives are reduction of 20% greenhouse gas emissions by 2030; reduction of 60% emissions from the transport and mobility; developing and establishing sustainable fuels and propulsion systems; reducing half of the conventional cars use in urban areas by 2030 and completely by 2050; attaining CO2 free city logistics in urban areas by 2030 *(The Ministry of Economic Affairs, 2017).*

In the Netherlands, according to the climate agreement held at the Hague the main goal is to reduce carbon emission by 2030. The Dutch government has decided to limit GHG emission by 49% as agreed in the Paris agreement. At the EU level, the government is striving to reduce 55% GHG by the year 2030. The government goal of 49% may vary as a large majority of member states affirming climate neutral by 2050 *(Climate Agreement, 2019)*. The maximum CO2 emission of 70 g/km in 2025 and an average of 35 g/km in 2030 is proposed to be achieved by the Netherlands *(The Ministry of Economic Affairs, 2017).* Electric vehicles are alternate for the internal combustion engine vehicles which uses fossil fuel as main energy source. The energy efficiency of EVs is about 75% whereas the ICE is very low and dependent on oil. Since, the Netherlands is an oil dependent country transition to EV has more advantages including the reduction of CO2 emissions and are less affected to rising oil and gas prices in the international market. EVs emits small amounts of CO2 and PM10 which has positive effect on the environment *(Hein, L.G., Bulk, D.V.J. 2009).*

EVs has certain limitations like economical challenge, underdeveloped EVs cannot take on ICE vehicles because of high selling price which limits penetrating to existing markets. The high selling price is due to high cost, supply chain issues of Li-ion batteries in the battery production. The EVs can be made affordable for high charging stations by reducing the battery costs. The public charging infrastructure plays a vital role in stimulating EVs and curbing the range anxiety of the users. (Faizal et al., 2019). The range anxiety is due to uncertainty in trip lengths, availability of charging infrastructure and the energy consumption. This problem can be overcome by developing more charging networks which guarantees the possibility to recharge and cover the maximum range (*Neubauer & Wood, 2014).*

One of the main challenges the Netherlands is facing transition mobility, the government has an ambition to attain zero emission by 2030, which corresponds to 1.9 million EVs and electricity requirement of 7,000 gigawatt hours where 1.7 million charging points are required. As per the calculations, from 2025 minimum of 550 charging stations must be installed every day. According to the ratio the common charging stations has a range of only about 15% to 18% and increasing load volume is distributed to fast charging networks. To meet the demand in 2030, everyday 217 public charging stations must be installed *(National Agenda Charging Infrastructure 2019).* The 60% of the Dutch people park their vehicles in public space is a concerning issue in the charging infrastructure. Ideally, citizens park EVs in their own property, it is very easy to install charging stations to charge EVs overnight. This is done by connecting charger directly to the house electric system, with the added probability of charging with solar energy from the house which is independent from the grid and increases self-sufficiency. This system is very easy to install, and citizens don't have to depend on public charging infrastructure. This is not available for most of the EV drivers, so they would depend on the public charging stations. Hence, the Netherlands examines the implementation of new regulations making sure the right of each EV driver on a charging stations within the acceptable distance to their houses *(Ministerie van Infrastructuur en Milieu, 2014).*

Static and dynamic charging are the two techniques in charging and the problem is not all the EVs can use these techniques for the charging. The expected EVs in future will add more pressure to the charging infrastructure, needs to upgrade with increase in EVs. Health of the battery storage and optimization of size, range anxiety and use of sustainable energy sources are also important challenges with extensive EV deployment. Major problems in setting up new charging infrastructure is because initial costs for installment is very high and profit is less. policy makers are facing challenges for formulating policies with the EVs and charging infrastructure. This is because of developments in new technologies like smart charging, wireless charging and fast charging, this requires the government to spend more money on upgrading the current system and establishing new stations by providing subsidies and tax incentives to the individuals. The current refueling behavior is different from the behavioral patterns like charging frequencies, length of charging sessions and kWh, understanding this is difficult and makes it hard to predict the demand, which enhances the charging infrastructure. Decisions on when and how to roll-out of charging infrastructure is very important. Postponing the decisions will increase the barriers and stops the transition to a sustainable transport system.

1.1 Research Objectives

The main objective of the study is to investigate the challenges and opportunities in terms of the technical performance and stakeholder involvement for strengthening the electric charging infrastructure for e-mobility in the Netherlands**.**

1.2 Research Questions

Main research question:
Can the energetic performance of the Dutch charging infrastructure for E-mobility in the Netherlands be improved by technology and integrated stakeholder perspectives?

The main question was addressed by answering the follow sub-questions.

1. How is the current infrastructure for E-mobility charging in the Netherlands organized technology-wise, organizational wise looks and what is the technical performance of the current system?

2. Which technological innovations are expected by key stakeholders to improve the technical performance of the charging infrastructure?

3. What are the current and future policies involved in uptake of electric vehicles and charging infrastructure in the Netherlands?

2. CURRENT STATUS OF CHARGING INFRASTRUCTURE

While analyzing the future scenarios, the development towards the current situation is the logical starting point. This chapter helps to understand existing situation which is done in three sections. First, the current charging technology is analyzed in section 2.1, followed by key organizations involved in section 2.2 and finally the technological performance of the charging infrastructure is analyzed in section 2.3.

2.1 Current Technology in Charging

The most significant part in the current charging technology is battery technology and charging technology. The battery technology describes the characteristics of the battery, structure of the battery and the chemical composition of the battery. In charging technology, different types and modes of charging techniques and the connectors used to charge the EVs are analyzed.

2.1.1 Battery Technology

Development of new battery technology can promote a higher number of EVs in the future. There are many kinds of battery, but currently predominant battery technology in EVs is Lithium-ion batteries which made them a market leader due to its specific energy (Wh/kg), life cycle and high efficiency. There is no ideal competitor for the electric powertrain, Li-ion battery remains as a good choice *(Miao, Hynan, Von Jouanne, & Yokochi, 2019).* At the time of charging, energy transfer speed is dependent on current and voltage. Power is equal to current multiplied by voltage with the same voltage, a lower current will reduce the energy transfer rate, which results in a lower charging speed of the batteries. The charging of a Li-ion battery happens in three phases. The first phase is also called as ‘pre-charge’ phase occurs when charging is initiated, voltage gradually increases when current is kept low. Most EVs charging of the battery occurs in second and third phase which is illustrated in the figure 2.1. The second phase known as constant current (CC) phase is initiated when the EV has minimum of 10% of a State-of-Charge (SOC). EVs with initial SOC higher than 10% will be a no significant pre-phase. During second phase, the high current is kept constant until it reaches specified voltage levels. The third phase of the charging starts at this point, voltage is kept constant and the current starts declining exponentially, with a trickle current the battery is charged and consequently the charging of the battery is slower *(Mies, Helmus, & van den Hoed, 2018)*.

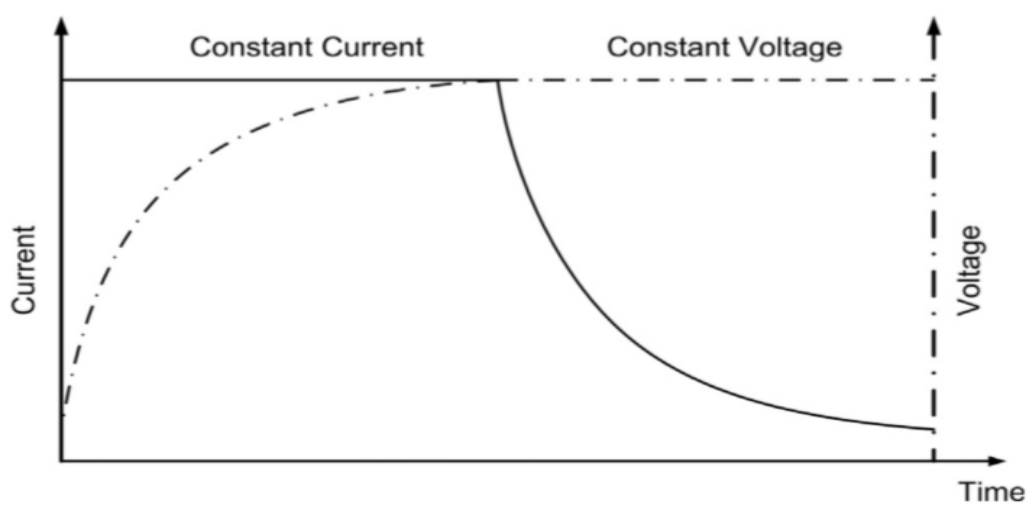


Figure 2.1: The charging profile of Li-ion battery (Mies, Helmus, & van den Hoed, 2018).

In general, Li-ion batteries are described as energy storage systems that depend on insertion reaction from both electrodes where lithium acts as the charge carrier. The Li-ion battery family consists of number of cell chemistries. For a cost-effective high capacity battery, the precise combination of positive and negative electrode material must exist. Electrolytes allows ion transfer in the battery; a separate membrane allows lithium ions to pass between positive and negative electrodes and avoids internal short circuit *(Miao, Hynan, Von Jouanne, & Yokochi, 2019)*.

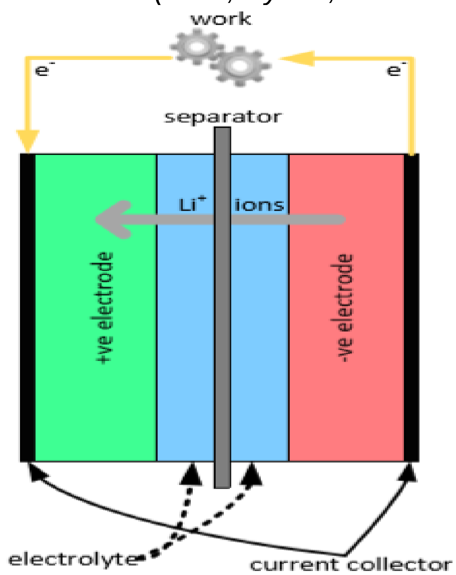


Figure 2.2: The schematic representation of the Li-ion battery (Miao, Hynan, Von Jouanne, & Yokochi, 2019).

The battery arrangement is shown in the figure 2.2. when battery is working as an energy source (a galvanic device), the electrons in the negative electrode move to the positive electrode, at the same time Li+ ions travel from negative electrode to positive electrode through electrolyte to maintain electroneutrality. During the charging mode (as an electrolytic device) the Li+ ion and electron current movement is inverted. Under the use conditions the electrolyte has to offer maximum possible lithium ion transport. In the general environment, batteries must operate in extreme cold (e.g., -30 °C) when the vehicle is parked for a period to +30 °C for a battery that has heated as a result of heat generated by charging and environmental conditions. Under the same working conditions as electrolytes, the separate membrane must provide the highest possible Li-ion conduction and obliged to offer the capability for fast thermal halt to avoid thermal runaway process if substantial overheating arises. The most significant aspects of a battery are specific power, specific energy, performance, safety lifespan, and cost *(Miao, Hynan, Von Jouanne, & Yokochi, 2019)*.

2.1.2 Charging Technology

DC charging
The technology converts AC from the grid to DC, charging the battery of the EV takes place externally to the vehicle with the high power of > 22 kW and the car battery has direct connection with the charging point *(RVO, 2018a).*

AC charging
The technology converts AC from the grid to DC, charging the battery of the EV takes place internally to the vehicle. The capacity of AC-DC converter in the car determines how much of

power that can be used from the charging stations. Usually charging speed is slower in this AC charging however, it is possible to charge at > 22 kW in AC fast charging *(RVO, 2018a).*

Fast charging

Fast charging can also be known as quick charging or rapid charging which is used to recharge the battery within less time like refueling of conventional vehicles. The battery of the EV is charged up to 80% capacity with a time of about 20 minutes, this will increase the traveling distance of the EVs provided adequate charging points are on the way. Fast charging module gives output of 35 kW or even higher with the corresponding voltage rating of 45 - 150 V and current rating of 20 - 200 A *(Chau, 2014).*

Charging technique

Charging technique (communication, capacity, safety) is also standardized and it is also referred to as charging mode. Charging mode is distinguished into 4 types and charging can be done with AC and DC. In mode 1 charging can, be done by using 230V AC socket with maximum capacity of 2.3 kW at 1 phase and 10A (230V * 10A = 2300W = 2.3 kW). Mode 2 uses a cable along with In-Cable Control Box (ICCB) which is a current limiter through which charging is done with the voltage of 230V regular socket or at a home charging station (AC). Practically, mode 2 has a charging capacity of maximum 2.3 kW at 1 phase and 10A but, maximum charging capacity of 7.4 kW can be delivered with 1 phase and 32A or 22 kW with 3 phase and 32A with the ICCB controller. Mode 3 is also called controlled charging. The vehicle communicates with the charging station to determine the charging capacity (AC). Mode 3 has the capacity to deliver the power of 11 kW, 22 kW or sometimes 43 kW. Any charging stations which deliver more than 22 kW are called fast chargers. Modes 1 to 3 uses AC and converts into the DC to the battery by the converter in the car. Mode 4 is DC charging which is more often used for fast charging, which AC is converted to DC in the charging station itself and without a converter. Mode 4 delivers power which varies between 50 kW to 175 kW, but it depends on the charging infrastructure and grid connection. The figures from 2.3 to 2.6 shows the different types of charging modes *(RVO, 2018a).*

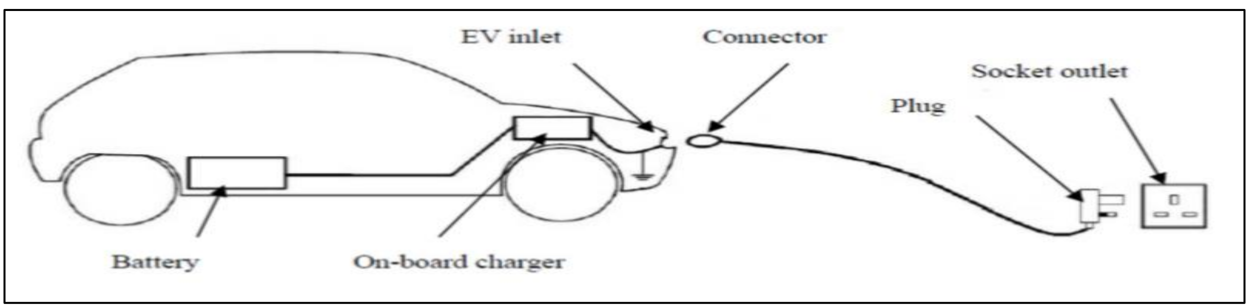


Figure 2.3: Charging Mode 1 (RVO, 2018a).

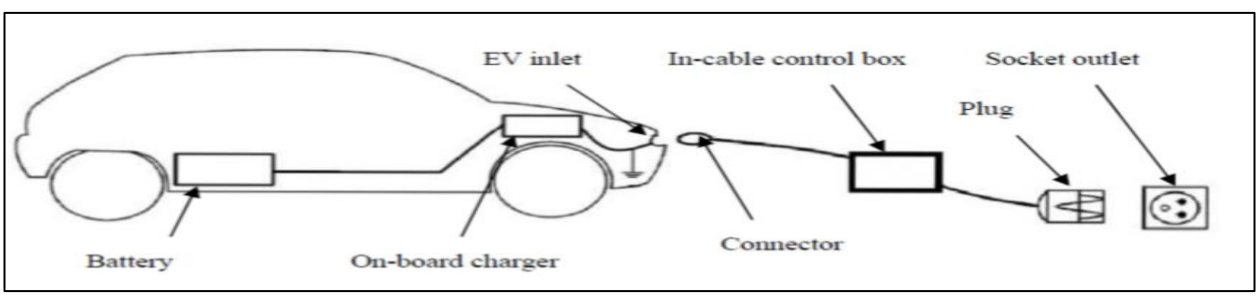


Figure 2.4: Charging Mode 2 (RVO, 2018a).

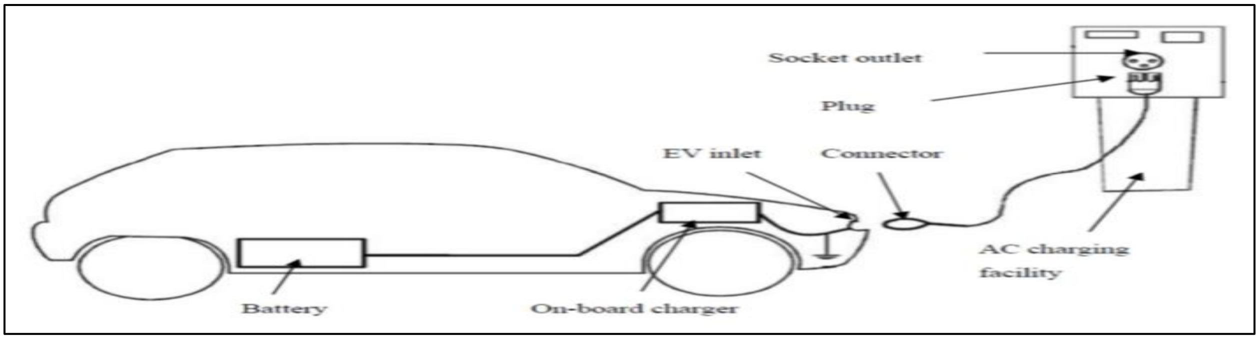


Figure 2.5: Charging Mode 3 (RVO, 2018a).

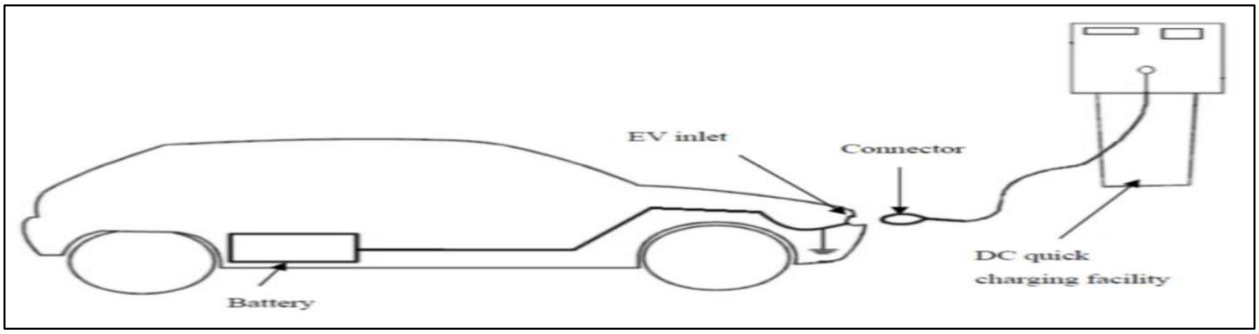


Figure 2.6: Charging Mode 4 (RVO, 2018a).

Besides the four charging techniques/modes, different connectors also exist. A connector is a cable which connects the car to the charging stations. Connector type 1 is a connector for charging electric vehicles (AC). Type 2 connector is used for charging EV of the power ≤ 22 kW (AC) is authorized by the Commission of the EU. Combined Charging System (CCS Combo 2) connector is an improved version of type 2 connector with high power for fast charging and this connector is compatible with both AC and DC and has been a standard connector for fast charging in Europe since 2017. Connector type 4 (CHAdeMO) is used for fast charging (exclusively DC). Tesla Supercharger is a connector that only works with the tesla cars and its configuration is like type 2 connection, but slightly modified, because of this reason it doesn't fit standard type 2 connectors *(RVO, 2018a).* The figures 2.7 show the different types of connectors and figure 2.8 shows an overview of the combination of charging modes and connector types.

Type 1 connector Type 2 connector

Type 3 connector Type 4 connector

Figure 2.7: Types of connectors (RVO, 2018a).

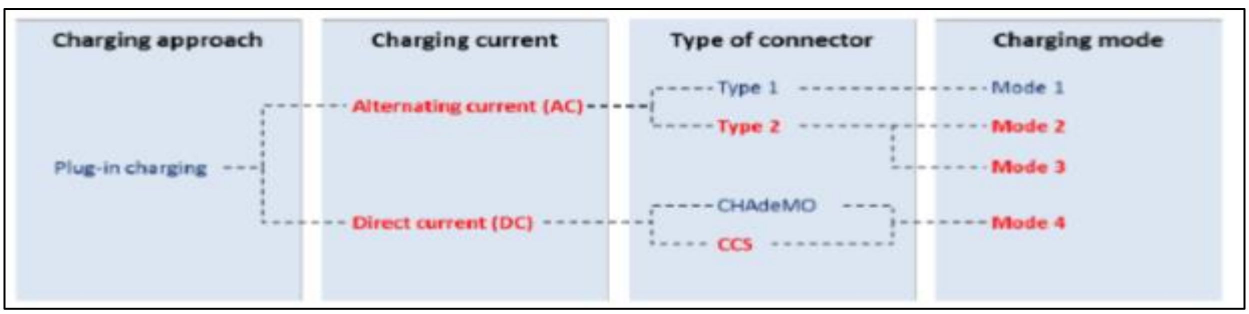


Figure 2.8: An overview of the combination of charging modes and connector types (eMAP, 2015).

2.2 Key Organizations Involved

Several organizations involved in the technologies of electric vehicles, the stakeholders involved are The Ministry of Economic affairs is responsible for legislations involving EVs and charging infrastructure on the national level. The Ministry of Infrastructure and Environment is responsible for formulating laws, policies, conduct inspection within the laws and policies and their objective is to stimulate E-mobility. RVO provides information, communication, innovation and advise to entrepreneurs in sustainability. Formula E-team place a vital role in shaping policy during the transition period to EVs. Foundation E-laad facilitates the roll-out of public charging stations to understand the charging behavior. Municipalities, Energy Providers, Grid Operators and Charging station Operators are the other stakeholders involved. A long-term agreement on the development of public charging infrastructure was always challenging as these stakeholders have conflicting interests. These stakeholders are discussed further below.

The Ministry of Economic affairs

The Ministry aims to assess the Netherlands to become a sustainable society. It promotes innovation and growth to create an improved international competitiveness of the Netherlands. The ministry plays a vital role in the Netherlands as they support the front running position in several sectors like agriculture, energy, and sustainability. Interests of the Ministry lies to stimulate the green growth and entrepreneurs in the field of public charging infrastructure. The legislations involving EVs and charging infrastructure on the national level are responsibilities of the Ministry of Economic affairs *(Rijksoverheid, 2016b)*.

The Ministry of infrastructure and Environment

The responsibility of this Ministry is accessibility and livability of the Netherlands, as they improve and maintain the connectivity of all transport sectors. The aim is to monitor and improve air, water quality, and protect against the flood, it's done to ensure a safe and healthy environment. The ministry also formulates laws, policies and conducts inspection with the laws and policies. It also contributes in EVs together with the Ministry of the Economic affairs to improve the upliftment of the EVs and the charging infrastructure. One of its main objectives is to stimulate electric mobility and to increase air quality in the urban areas *(Rijksoverheid, 2016c).*

RVO

The Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland) comes under the Ministry of Economic Affairs and derives from Dienst Regelingen and Agentschap NL in 2014. This organization works closely with the governments, international organizations, knowledge centers like E-laadNL, and entrepreneurs. This organization also provides information, communication, innovation, and advice to entrepreneurs in sustainability. The RVO also helps in providing networks, grants, knowledge and compliance with regulations and laws. The RVO's website publishes the data on number of EVs and charging stations in the Netherlands (*RVO, 2016a).*

Formula E-team

It is a public private partnership of the umbrella of the organizations such as knowledge institutes, the government, NGOs, and the business community. The goal is to develop E-mobility to a great extent in the Netherlands and to utilize opportunity to promote green growth. The Dutch government has set a goal of selling zero emission cars by the year 2030, with several other organizations the government created Formula E-Team. Formula E-Team played a vital role in shaping policy during the transition period to EVs. They also successfully lobbied the green deal publicity accessible electric charging infrastructure, where 12 parties signed. The objective is to reduce the total cost of the building and exploiting publicly accessible charging infrastructure by 70% in the year 2017. Innovative projects and knowledge exchange are provided by the National Knowledge Charging Infrastructure Platform (NKL) *(RVO, 2018b).*

Foundation E-laad

It is an initiative from several electricity organizations such as Alliander, Cogas, Endinet, Stedin and Westland Infra *(EVnetNL, 2016).* The objective is to facilitate the roll out of public charging stations to understand the charging behavior. Approximately 350 Dutch municipalities worked along with the E-laad to install public charging stations, as they installed chargers for free and took care of maintenance and breakdowns. As a result of this the public charging stations increased to 3000 in the year 2014. But there were issues with the transmission system operators in supplying public charging infrastructure. The Dutch government is the owner of the electric transmission system; their role excluders the commercial activities such as operating public charging infrastructure. This led to the split of E-laad into two new foundations ElaadNL and EVnetNL, where ElaadNL provides knowledge and innovation institutions providing help to government and market players to find the efficient place for charging infrastructure. They stimulate the charging infrastructure towards the cheaper and smaller charging stations with better efficient regulations and take care of registrations and reviewing permits *(ElaadNL, 2016)*.

ElaadNL was the founding organization of the National Knowledge Platform Charging infrastructure. Its aim is to link organizations in the quest to minimize the cost of public charging *(NKL, 2016a).* They stimulate development in the charging sector, facilitate innovative projects and support them and ensure knowledge exchange. This process by the National Knowledge Platform Charging infrastructure emphasizes the public charging sector of the Netherlands. The current NKL's programs are Sector Optimization, Protocols and Standards and Smart Charging *(NKL, 2016a).*

EVnetNL manages the charging stations in a unique network of public charging points as they collaborate with the municipalities involved. In 2016, EVnetNL offered municipalities to take over the EVs charging stations installed by them, which was welcomed by most of the municipalities and they opted for it. Currently, 800 poles in 200 municipalities are managed by EVnetNL as they take care of maintenance, solving malfunctions and keeping software up to date so charging points functions optimally *("Organisatie | EVnetNL", 2020).*

Municipalities

Municipalities may take up roles like reactive, incentivizing and facilitating depending on policies and ambitions. If a resident, provider, or company contacts the municipality for seeking permission for installing the new stations in office or near their house, in this case an exemption from section 2:10 is required. There are certain rules under the exemption in which municipalities may impose requirements to the applicant. When municipality itself takes the initiative for setting up new charging stations in the city in this case municipality has mere authority for granting license and laying down the traffic orders. In addition to all of these, the municipality provides subsidies for charging infrastructure to put in place for dwellings and/or businesses *(The Ministry of Economic Affairs, 2017).*

Energy providers

In the Netherlands TenneT provides electricity, it is responsible for construction and maintenance of the national high voltage grids of 110, 150, 220 or 380 kV. The regional electricity (66 kV) are taken care by seven regional grid operators. TenneT connects the Dutch electricity grid with the capacity of approximately 100 MW and approximately less than 100 MW electricity is provided by relevant regional network operators like Liander and Stedin *("Connecting to the Dutch high-voltage grid", 2020).* Regional grid operators or Distribution System Operators (DSO) is the organization that designs, operates, and maintains public distribution low and medium voltage and transports to the charging spots. Charging spots connected to private grids like houses, installation sites, buildings and so on which in turn connected to the DSO. Higher peak demand could occur with the increase of the EVs, so the large investments were to be made from the operators to establish net balance *(RVO, 2018a).*

Charge Point Operator (CPO)
Charge point operators are also called Spot Operators responsible for the maintenance, management, and proper operations of the electric charging stations. CPO is also responsible for administrative operations like access, roaming and billing to MSP, technical maintenance which will be done by the charging stations manufacturers *(RVO, 2018a).*

E-Mobility Operator - Mobility Service Provider (MSP)
Mobility Service Provider is responsible for all the contract services related to the EV operation by the EV driver. The other actors involved are energy providers or a CPO and it also maintains the close relationship with the meter operator and DSO. It also authenticates the contract IDs from the customers which is received from the CPO, MSP or other E-mobility operators *(RVO, 2018a).*

The following charging networks are known to operate in the Netherlands
Alfen, Allego BV, Blue Corner (Belgium), ChargePoint (Coulomb Technologies), Ecotap, E-Laad, Eneco, Enovates, Essent(NL), EV-box, EVnetNL, EV-point, Fastned, Flow charging, Green flux, In charge, Ionity, Last Mile Solutions, Lidl, Mister green (the fast charger network), Nomad power, Nuon, Park & Charge(D), Pod-Point(UK), RWE Mobility/Essent, Stadtwerke Clausthal-Zellerfeld, Tesla Motors, The New Motion, The plug in company, Vattenfall Incharge *("Open Charge Map – Charging Networks in Netherlands", 2020).*

2.2.1 Market Model

Under the direction of central government in the year 2012, Innopay established a market model for use of charging infrastructure payments. It involves several types of business including energy companies, mobility providers, and interest groups. Two key factors are standardized: Interoperability and the ability to charge for a user's consumption of electricity *(The Ministry of Economic Affairs, 2017).* Interoperability assurances the ability of an EV owner to charge at any charging stations, irrespective of the charging station location, the type of EV and the charging infrastructure provider. The Netherlands is the only one nation in the world where operability is guaranteed at a national level. The Open Charge Point Interface (OCPI) provides consumers and business with a way to transfer data easily and it contains data on charger specification, charger availability and charging costs *(NKL, 2016b).*

The market model is shown in figure 2.9**.** The transaction starts at the consumer, where consumer can identify himself with a card or an app to start the charging procedure. The card is provided by the Mobility Service Provider (MSP). An MSP keeps the record of amount of electricity transferred by the consumer and charges the consumer for it, with a small fee for the identification card. The EV owner is provided with only one identification card, hence they have one MSP. Here interoperability principle guarantees that the EV owner can charge at any charging station with their identification card *(Agentschap NL, 2012).* The infrastructure provider is accountable for the supply, installation, and maintenance of the charging stations. The Charge Point Operator (CPO) guarantees that the charging stations is available to supply electricity. The CPO charges the MSP for the electricity supplied and MSP receives an overview of where and how much the consumer charged. The MSP combines charging sessions and charges the consumers *(Agentschap NL, 2012).*

There are some crucial starting points for the central government when this market model developed, and which is still in place were freedom of choice in respect of the relationship with other players, competition: competitive and dynamic market with transparent admission norms. Convenience: simplicity and uniformity, Cost effectiveness: optimize for Small and Medium scale Enterprises (SME) admission, Future-proof: able to respond flexibility to technological changes, Self-regulating and requiring no amendment of legislation and regulations, and the government will act as facilitator, regulate and help start the process *(The Ministry of Economic Affairs, 2017).*

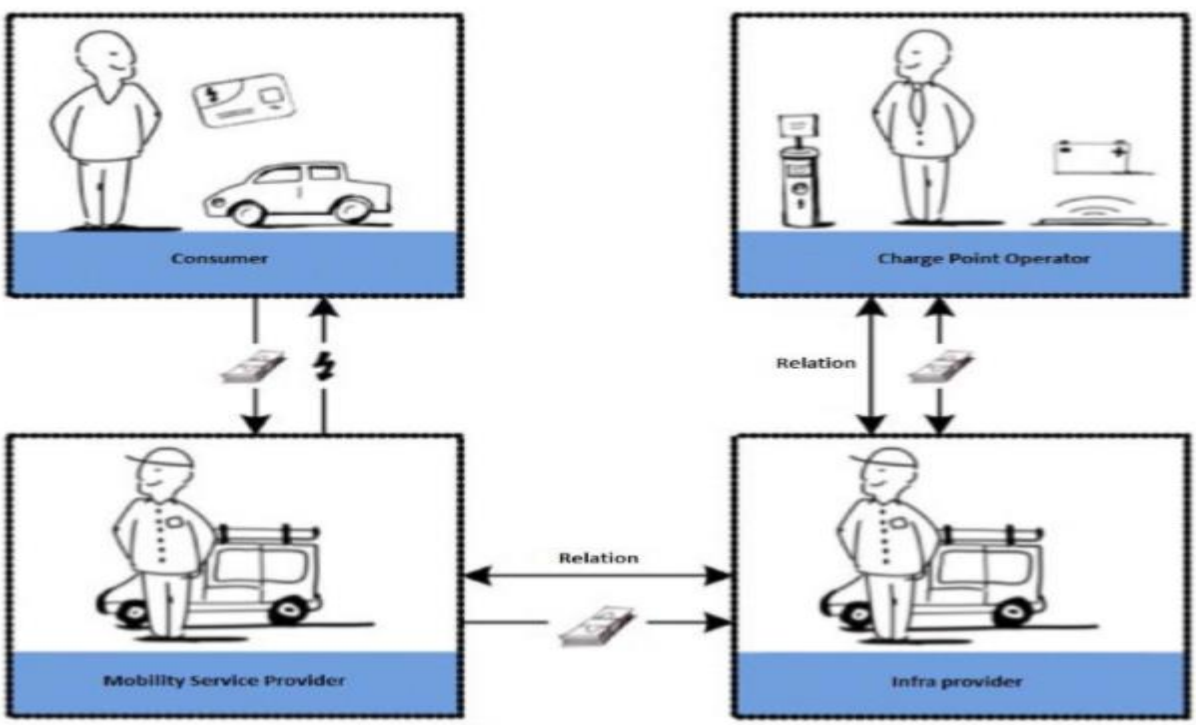


Figure 2.9: The market model for public charging in the Netherlands *(Agentschap NL, 2012).*

2.3 Numbers

The RVO publishes data on the number of EVs and charging stations in the Netherlands. The figure 2.10 shows the number of EVs, market share, fast charging stations, newly registered EVs, semi-public charging points, and jobs within E-mobility sector (*RVO, 2020).*

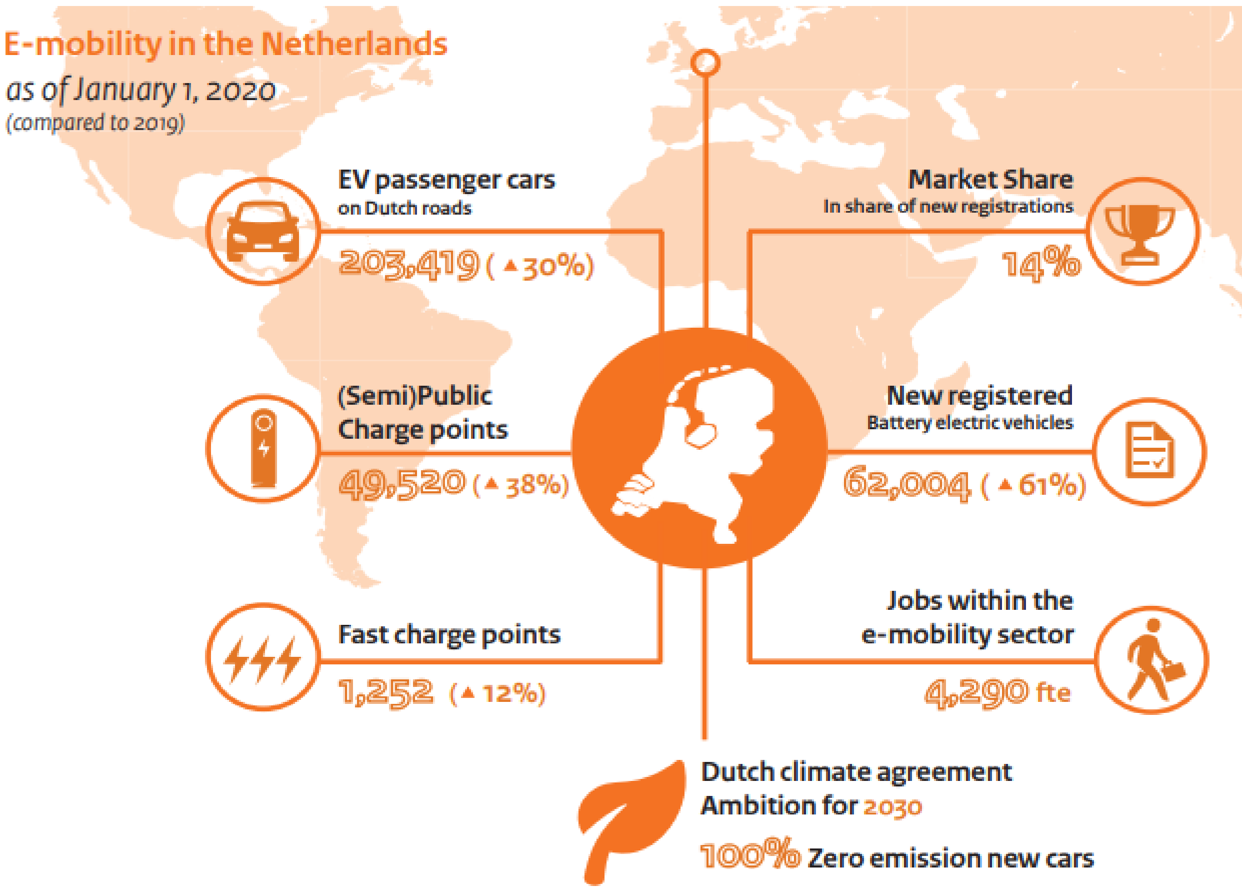


Figure 2.10: The number of EVs, market share, fast charging stations, newly registered EVs, semi-public charging points, and jobs within E-mobility sector (RVO, 2020).

In the Netherlands RVO publishes the latest information about the new charging points which helps EV drivers to find public and semi-public charging stations using the website oplaadpalen.nl. Charging stations are divided into four categories based on location and accessibility of the charging stations. Public charging stations, as these stations are standard charging points in the public places and can be accessible to 24 hours a day and seven weeks in a week. Semi-public charging stations can also be accessible to the public, but these may be restricted to the access or the public because of availability of parking and the opening times. For example, underground car parks, at hotels, catering establishments and/or service stations. Fast charging stations, act as a bridge connecting long distance when it is not possible to charge at the park. These stations are installed in specially designed sites in strategic positions. Here charging takes place at a higher rate which helps EV drivers to charge their vehicle in less time. For example, next to the motorway. Private charging stations: These stations cannot be accessible to the public more often because these stations are installed in the private site and connected to the private electricity supply. Some stations are installed by the employer in the company for their employees who owns the EV. When a car is purchased, car manufacturers offer charging stations to their home *(The Ministry of Economic Affairs, 2017).* The figure 2.11 shows the number of public, semi-public, fast and private charging stations in the Netherlands in the current year (2020) and numbers expected in the year 2030.

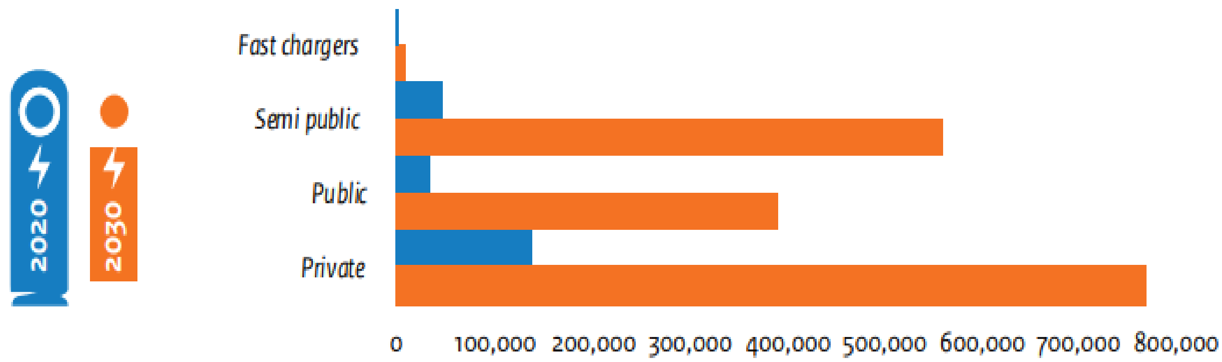


Figure 2.11: The number of public, semi-public, fast and private charging stations in the Netherlands in the year 2020 and 2030 (RVO, 2020).

2.4 Technological Performance

The EU has a target of achieving 100% emission free from the transport sector, this requires policy formulators and CPOs to know the current performance of the charging infrastructure. In the Netherlands charging infrastructure encounters various challenges over the years, 100% demand driven roll out strategy is no longer tenable. To adapt to the current situation, it is necessary to evaluate the real-life charging data and Performance Indicators (PI) provides guidance to increase the result. The objectives of local authorities, CPOs, grid operators, EV users and residents (non-EV users) resulting to thirteen performance indicators. There is no proper knowledge on defining key performance indicators for a charging infrastructure, but Huang et al provided a scientific model to optimize the charging infrastructure. It gives an outline of optimization metric like minimizing overall travel time, trip failure, number of charging stations, grid management, several charging infrastructure cost types and maximizing flow captured, covered demand and charging post usage *(Maase, Dilrosun, Kooi, & van den Hoed, 2018).*

Assessment tool is a web-based application with built in R package shiny and contains three webpages of a map and two KPI tables. There is also a fourth assessment tool that has been developed, implemented, and provides the opportunity to assess a complete infrastructure visualization as shown in the figure 2.12. KPI table is used to know the performance indicators (kWh, connection time, charging time, number of sessions) of the charging infrastructure and nonperformance indicators (number of unique users per month, average occupancy) is shown in Figure 2.13 *(Maase, Dilrosun, Kooi, & van den Hoed, 2018)*.

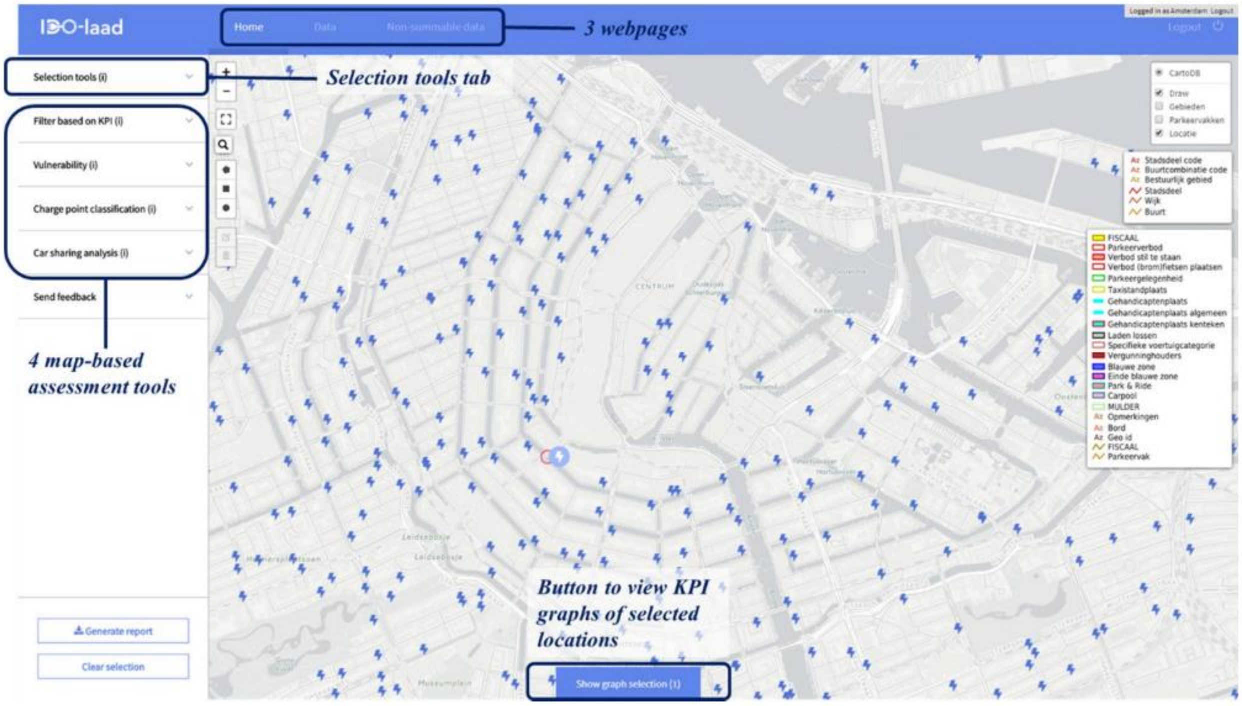
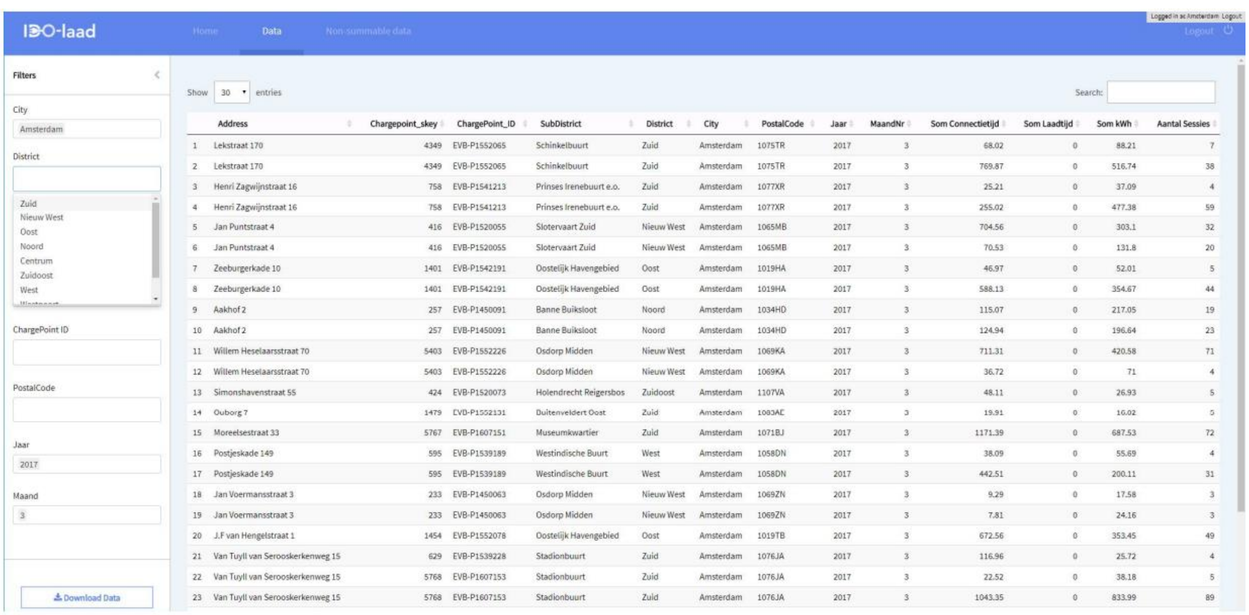


Figure 2.12: Homepage including explanatory textboxes (Maase, Dilrosun, Kooi, & van den Hoed, 2018).



	Address	Chargepoint_skey	ChargePoint_ID	SubDistrict	District	City	PostalCode	Jaar	MaandNr	Som Connectietijd	Som Laadtijd	Som kWh	Aantal Sessies
1	Lekstraat 170	4349	EVB-P1552065	Schinkelbuurt	Zuid	Amsterdam	1075TR	2017	3	68.02	0	88.21	7
2	Lekstraat 170	4349	EVB-P1552065	Schinkelbuurt	Zuid	Amsterdam	1075TR	2017	3	769.87	0	516.74	38
3	Henri Zagwijnstraat 16	758	EVB-P1541213	Prinses Irenebuurt e.o.	Zuid	Amsterdam	1077XR	2017	3	25.21	0	37.09	4
4	Henri Zagwijnstraat 16	758	EVB-P1541213	Prinses Irenebuurt e.o.	Zuid	Amsterdam	1077XR	2017	3	255.02	0	477.38	59
5	Jan Puntstraat 4	416	EVB-P1520055	Slotervaart Zuid	Nieuw West	Amsterdam	1065MB	2017	3	704.56	0	303.1	32
6	Jan Puntstraat 4	416	EVB-P1520055	Slotervaart Zuid	Nieuw West	Amsterdam	1065MB	2017	3	70.53	0	131.8	20
7	Zeeburgerkade 10	1401	EVB-P1542191	Oostelijk Havengebied	Oost	Amsterdam	1019HA	2017	3	46.97	0	52.01	5
8	Zeeburgerkade 10	1401	EVB-P1542191	Oostelijk Havengebied	Oost	Amsterdam	1019HA	2017	3	588.13	0	354.67	44
9	Aakhof 2	257	EVB-P1450091	Banne Buiksloot	Noord	Amsterdam	1034HD	2017	3	115.07	0	217.05	19
10	Aakhof 2	257	EVB-P1450091	Banne Buiksloot	Noord	Amsterdam	1034HD	2017	3	124.94	0	196.64	23
11	Willem Heselaarsstraat 70	5403	EVB-P1552226	Osdorp Midden	Nieuw West	Amsterdam	1069KA	2017	3	711.31	0	420.58	71
12	Willem Heselaarsstraat 70	5403	EVB-P1552226	Osdorp Midden	Nieuw West	Amsterdam	1069KA	2017	3	36.72	0	71	4
13	Simonshavenstraat 55	424	EVB-P1520073	Holendrecht Reigersbos	Zuidoost	Amsterdam	1107VA	2017	3	48.11	0	26.93	5
14	Ouborg 7	1479	EVB-P1552131	Buitenveldert Oost	Zuid	Amsterdam	1083AE	2017	3	19.91	0	16.02	5
15	Moreelsestraat 33	5767	EVB-P1607151	Museumkwartier	Zuid	Amsterdam	1071BJ	2017	3	1171.39	0	687.53	72
16	Postjeskade 149	595	EVB-P1539189	Westindische Buurt	West	Amsterdam	1058DN	2017	3	38.09	0	55.69	4
17	Postjeskade 149	595	EVB-P1539189	Westindische Buurt	West	Amsterdam	1058DN	2017	3	442.51	0	200.11	31
18	Jan Voermansstraat 3	233	EVB-P1450063	Osdorp Midden	Nieuw West	Amsterdam	1069ZN	2017	3	9.29	0	17.58	3
19	Jan Voermansstraat 3	233	EVB-P1450063	Osdorp Midden	Nieuw West	Amsterdam	1069ZN	2017	3	7.81	0	24.16	3
20	J.F van Hengelstraat 1	1454	EVB-P1552078	Oostelijk Havengebied	Oost	Amsterdam	1019TB	2017	3	672.56	0	353.45	49
21	Van Tuyll van Serooskerkenweg 15	629	EVB-P1539228	Stadionbuurt	Zuid	Amsterdam	1076JA	2017	3	116.96	0	25.72	4
22	Van Tuyll van Serooskerkenweg 15	5768	EVB-P1607153	Stadionbuurt	Zuid	Amsterdam	1076JA	2017	3	22.52	0	38.18	5
23	Van Tuyll van Serooskerkenweg 15	5768	EVB-P1607153	Stadionbuurt	Zuid	Amsterdam	1076JA	2017	3	1043.35	0	833.99	89

Figure 2.13: Examples of a KPI list (Maase, Dilrosun, Kooi, & van den Hoed, 2018).

The map provided an instinctive interface for selecting desired charging locations rapidly to assess and compare the performance. Followed by this the selection tool helps to locate the level you want to calculate the KPIs and the part you want to see on the map. This search is based on the location level, project, charging point provider, use type, fast charging, and fast hub.

Assessment tool is a filter based on KPI, alters the color of the charging stations location markers in the map which is based on the KPI, KPI threshold, month and a year. After setting a KPI threshold, the performance of the charging location drops to the minimum threshold color green, color red if the threshold level is maximum then the installed range and if the location fits the installed range is color orange. The car sharing indicates the location were highly occupied vehicles as a part of a free-floating car sharing scheme. Depending on the maximum and minimum threshold occupancy rate different color codes were used. Green indicates less than 50% both during day and night, red indicates more than 50% both day and night. Blue represents more than 50% occupancy in day and less than or equal to 50% at night, whereas yellow is vice-versa *(Maase, Dilrosun, Kooi, & van den Hoed, 2018)*.

Vulnerability is an assessment tool that follows the principle of cascade failure, measures the usage of the charging location by the EV users as the effect of the competition. Users opt for an alternate location if a charging location is not available. Based on the charging data two indicators such as inconvenience and service failure were calculated by the vulnerability tool. The service failure indicates the fraction of regular sessions during a set period that could not be transferred to another location. Inconvenience counts the number of charging sessions that happen at an alternate location during a set period. More users will be affected due to the transferring of the charging sessions *(Maase, Dilrosun, Kooi, & van den Hoed, 2018)*.

2.5.1 Implementations of the Assessment Platform for the Detection of Charging Infrastructure Bottlenecks

With the increasing number of EVs and dense charging infrastructure in place, it is necessary to assess the charging infrastructure potential bottlenecks regularly. This is in place to be able to predict and sustaining of charging infrastructure with rising requirement.

Vulnerability Tool

Vulnerability tool helps in assessing the out of service charging locations, performance of charging infrastructure and adding new users. Expansions of the vulnerable charging locations depends on the number of cases due to service failure, either a new user entered, or the sessions could not be satisfied by the charging infrastructure. Development of the algorithms behind the tool like, generating the opportunity to include charging location manually and examining the effect on the vulnerability scores are being considered by the developers. Practical use case for the vulnerability tool is represented in the figure 2.14 *(Maase, Dilrosun, Kooi, & van den Hoed, 2018)*.

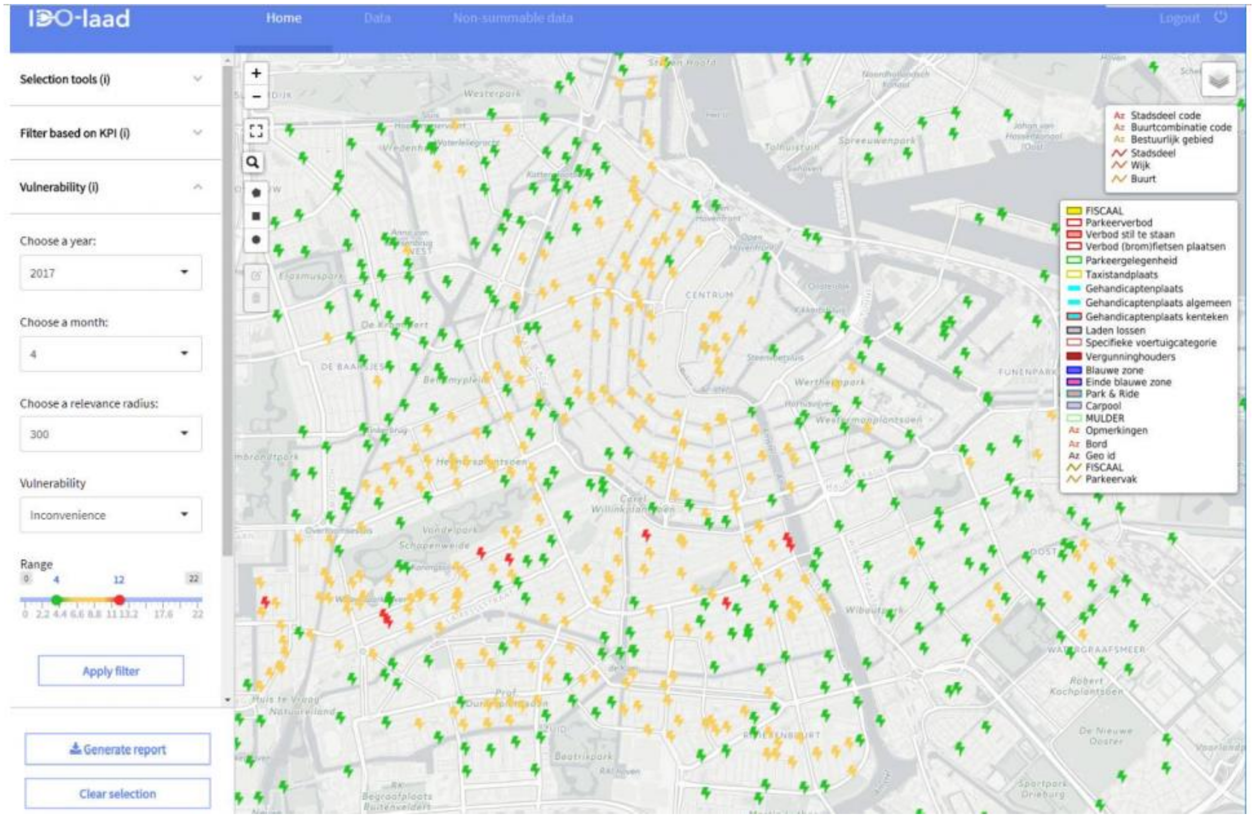


Figure 2.14: Inconvenience of the charging infrastructure Mat 2017. In red, the charging locations at which there were more than 12 unique users are being affected by one user added to the network (Maase, Dilrosun, Kooi, & van den Hoed, 2018).

Charge Point Classification Tool

Charging point classification tool is another tool which is crucial in detecting potential bottlenecks of the charging infrastructure. After selecting the desired month and year and clicking the "apply filter" button, popup the visual overview of each charging location average occupancy during the day and night on the map. In case of new requests for the charging infrastructure, practitioners set the threshold of 50% as a relevant trigger, if all the charging locations have average occupancy of more than 50% within 300m walking distance from the requester's address then new stations will be installed. In case the average occupancy is less than 50%, still if charging infrastructure has capacity to serve a new applicant then the applicant will be referred to charging stations. When the red location (hourly occupancy of more than 50%) has been detected, then the practitioners can start evaluating the single locations by examining their number of unique users, kWh charged, etc., to make right choices to develop the charging infrastructure to avoid future problems. The figure 2.15 indicates high hourly occupancy during both day and night *(Maase, Dilrosun, Kooi, & van den Hoed, 2018)*.

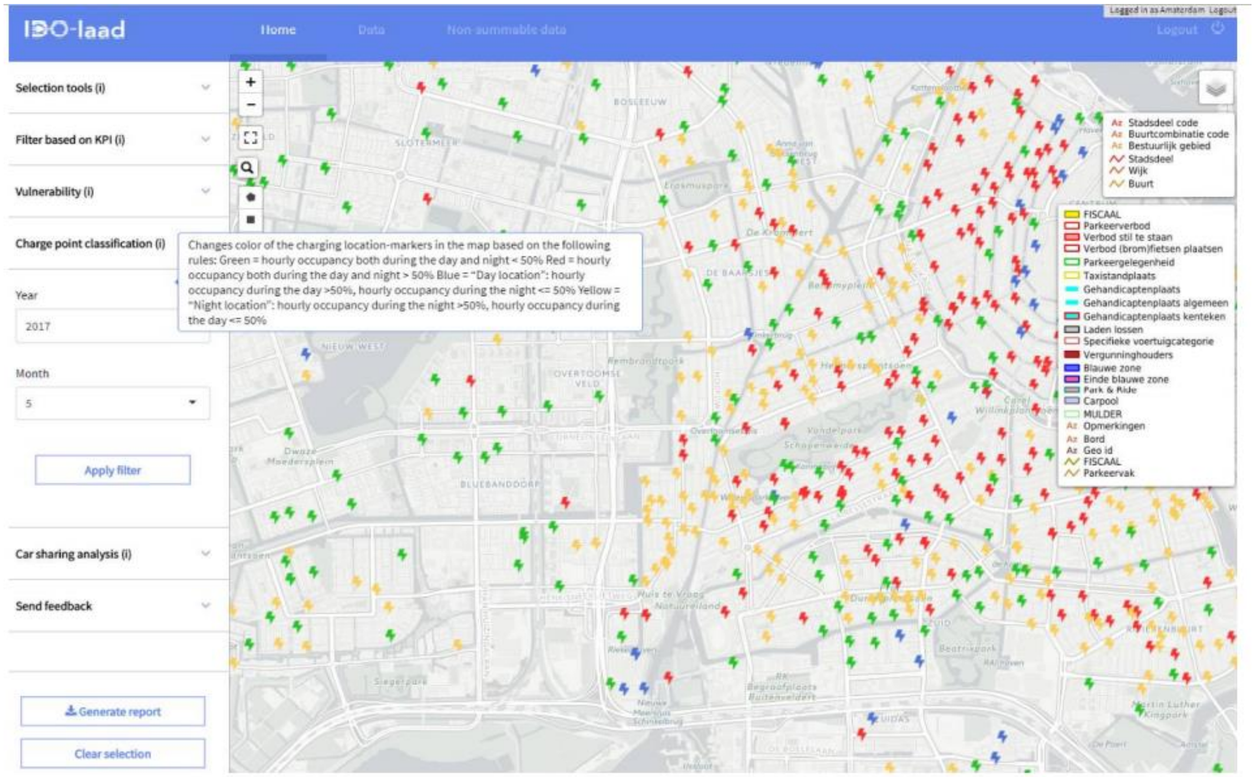


Figure 2.15: Charge point classification indicating high hourly occupation during day, night, or both (Maase, Dilrosun, Kooi, & van den Hoed, 2018).

Summarizing, Li-ion battery is used in most of EVs in the Netherlands due to its high specific energy, high efficiency and life cycle, the future battery technologies like Lithium Sulphur and Lithium air will have high specific energy and efficiency than the Li-ion batteries. DC fast charging helps in charging EV to 80% within 20 minutes but the number of fast charging in the Netherlands is still lagging. Mode 4 charging technique has a power to deliver DC at 50 to 175 kW. Type 2 connector is used to charge an EV which is authorized by the EU for charging < 22kW. Combined charging system connector is used for high power fast charging of EVs. There are many organizations involved in the field of charging infrastructure, the Ministry of Economic Affairs makes legislations to stimulate green growth and entrepreneurs in the field of public charging infrastructure. The Ministry of Infrastructure and Environment formulates and inspects laws and policies related to EVs and charging infrastructure. The Municipalities implement the policies made by the central government and provides public charging infrastructure. ElaadNL facilitates innovative projects and knowledge exchange between the companies to reduce cost of charging infrastructure. The market model ensures the freedom of choice, the government encourage small and medium scale industries to start a process by helping them to make it easier. The number of new registering EVs are increasing, but still lagging in the market share. Technological performance is analyzed using KPIs to know the performance of the existing charging stations based on the location. Depending on the maximum and minimum threshold occupancy rate different color codes were used to analyze performance. Detection of charging infrastructure bottlenecks is done by Using vulnerability tool and charge classification tool.

3. TECHNOLOGICAL INNOVATIONS

This chapter explores the future technological developments in the field of EVs and charging infrastructure in the Netherlands. The various technological innovations including sustainability which helps in uptake of EVs are discussed in detail below.

3.1 Smart Charging

Smart charging is a charging an EV that can be externally controlled, which allows adaptive charging habits, provides integration of EV to the whole power grid in a user-friendly environment. It should take care of the supply along with meeting the mobility constraints and user requirements *(RVO, 2018a).* Grid-to-vehicle-technology which helps EVs to charge at varying capacities (automatically determines), depending on the availability of the energy. Depending on energy demand and available capacity on local level, batteries can be charged in a smart way to evict peak loads on the grid. Vehicle-to-grid-technology helps in optimizing the usage of sustainable energy and facilitates EVs to feed electricity back into the grid. When the production of energy is high, batteries of the vehicles can be used as guard to store energy and during the times of low energy production it acts as an energy supplier *(RVO, 2018a).*

In the Netherlands, many researches are going on smart charging such as Living Lab Smart Charging as a field trial in Overijssel and Gelderland. For the largest practical research in the Netherlands 4,500 new charge points in 43 municipalities has been used over the years. EV drivers can charge their vehicle in less time, unless they must specify that they need more power when there is strong demand for electricity and during outside the peak demand higher capacities are offered for the EV drivers. TenneT along with Vandevron maintain the balance in the electricity grid using smart charging and this can also be done by providing EV drivers a trial, financial support. In the provinces like Groningen and Drenthe the experiment of smart charging is focusing on free choice of energy suppliers, so that all energy provider companies can supply energy to charging stations installed in these provinces. Users are also given opportunities to load energy for the public charging infrastructure by generated energy from the solar panel or wind turbines *(RVO, 2019).*

3.2 Wireless Inductive Charging

Inductive or wireless or plug less charging is a charging technology used to charge EV when it is parked at the charging point from electromagnetic fields. Induction plate is placed on the surface of the road at parking space, the car drives over the plate and the car is charged by using an app designed for this *(RVO, 2018a).* Frequency bandwidth of around 81.39 to 90kHz is assigned for four classes of EV IPT wireless charging (3.7, 7.7, 11, 22kW). Alternating magnetic field produced will link with the secondary pad in the vehicle converted to the electricity by wireless power transfer. Charge pads are placed 10-15cm apart creating a large gap hence, in turn a large reluctance path. To attain high power at suitable efficiency, capacitive compensation is significant with well-defined magnetics to curtail power reduction during misalignment. For the IPT systems, charging pads is made up of coils wound in distinctive forms like, square, circular and rectangular. For large distance power transfer, research is carrying out in the field of multi-coil pads *(Venugopal, et al., 2018)*.

There are three types of wireless power transfer for EV charging have been developed. First, Stationary/Static Charging where no need of using high voltage power cables and parking lots can be updated with the charge pads to charge EVs. Second, Semi-Dynamic Charging is useful for charging the battery of the EVs during the opportune stop in a trip or slow-moving instances like stop lights and taxi ranks where energy can deliver back to the battery. Lastly, Dynamic Charging where battery life can be increased with small packets of energy which reduces range anxiety during long trips because of limited battery size. It shows that for an EV with battery capacity of 24kWh, by using an IPT system of 25kWh with 40% road coverage, 500km range can be attained *(Venugopal, et al., 2018).*

Various companies in the Netherlands are carrying out experiments on wireless charging of electric cars. The current is transferred to the car by electromagnetic fields when EV is parked at the charging point. The city of Rotterdam along with various companies developed a charging plate which allows EVs to recharge wirelessly. The EVs drives over an induction plate located on the exterior of the parking, with the help of an app charging can be initiated. But the technology is in its initial phase and it is not clear when this technology is available for consumer market, because the cars should also have induction technology installed in them. The cars used the experiment in Rotterdam had to be installed induction plate. This technology is introduced in Formula-E cars. In addition to wireless charging, work on new technologies is being carried out which will enable EVs to charge whilst being driven. This technology uses electromagnetic fields which can be used to transfer current to EVs in motion. Academically, the technology might allow EVs to travel for much longer distances by using electric power. Though, this technology's innovative nature makes it impossible to expect whether and when wireless charging will be available in the market *(The Ministry of Economic Affairs, 2017).*

3.3 Pantograph

A pantograph can be either on the vehicle or on the charging point. Pantograph on vehicle (pantograph up) is like the systems used in the trains and trams and can also be used for depot charging which needs cheap and light woods on top of the terminus. Pantograph on charging point (pantograph down), here vehicle has only contact point, means that vehicle has less weight and a favorable center of gravity and Wi-Fi acts as communication medium between EV and charging infrastructure in which signal must be well secured *(RVO, 2018a).* The figure given below shows the pantograph.

Figure 3.1: Pantograph (RVO, 2018a).

3.4 In-situ renewable energy generation and Solar Roads (SR)

Charging the EVs using sustainable energy helps in reducing emissions. The energy generated is delivered to a signal lightening system and roadways, additional energy generated is being stored in the batteries for future use. In addition to charging EVs, renewable energy (solar and wind) is utilized in the highways of the Netherlands. Demand and supply optimization of the small micro grids can be done using cyber physical networks in smart buildings. In this way renewable energy can be locally utilized, so transmission and distribution losses are reduced. Savings due to reduced renewable energy cost and improvement of range of EVs on wireless charging. Solar roads are a Dutch innovation, consisting of solar cells in a prefabricated concrete module laid on the ground with a surface layer of tempered glass through which light passes. Solar cells in a concrete module which converts solar energy into electricity. From this technology 9.69% maximum efficiency of the module is attained. Solar roads use PV technology as installation is simple, load bearing capabilities and low maintenance cost. Wind energy technologies consists of a micro turbine based disruptive technology- 4 kW bladeless vortex, a conventional wind turbine of 2 MW, bladeless vortex produces oscillating wind energy without use blades. This structure is made up of fiber glass and carbon fiber and uses the sheer force of wind that when falling onto the structure creates eddy currents, is converted into electrical energy by cutting a magnetic field produced by magnets in the base *(Venugopal, et al., 2018).*

3.4.1 Integration of solar roads with IPT

Solar roads are sandwiched in between the IPT system in this technology. A lab scale prototype is tested to practically understand a mechanism of magnetic coupling occurring between IPT coils sandwiching a solar road element. Measurements for mutual induction are conducted on IPT coils with and without solar cells. The frequency dependent mutual inductance is calculated and converted to coupling. It has been observed that coupling starts falling linearly after 10 kHz on a logarithmic frequency scale. As the IPT system would operate around 85 kHz resulting in coupling to ≈50% leads to reduction in efficiency. For frequencies greater than 10 kHz, it is assumed that mutual inductance decreases because of eddy currents in solar road conductive parts *(Venugopal, et al., 2018).* A thicker 10mm black aluminum surface is considered for a solar cell for adequate computational capability and removing the skin effect influence occurring at frequencies which is lower than 10 kHz where it generates eddy currents. When 1A of current at 50 Hz the primary coil is excited, the surface plot of induced eddy current is shown in the figure 3.2. The red arrows illustrate the direction of the coil current while the black shows the direction of opposing induced currents. Aside from eddy current, a frequency dependent decrease in the mutual inductance is also observed and mutual conductance between the IPT coils is calculated using the formula M = (Nprimary/Vpickup) * (Vpickup/jωIpickup). It is observed that mutual inductance decreases with increase in operating frequency. However, for 85 to 100 kHz the skin effect is not enough to limit the eddy current for IPT. Therefore, the power transfer ability drops down with lower mutual coupling. Further, due to heating losses in the solar cell back contact due to these eddy currents the efficiency of IPT operation falls *(Venugopal, et al., 2018).*

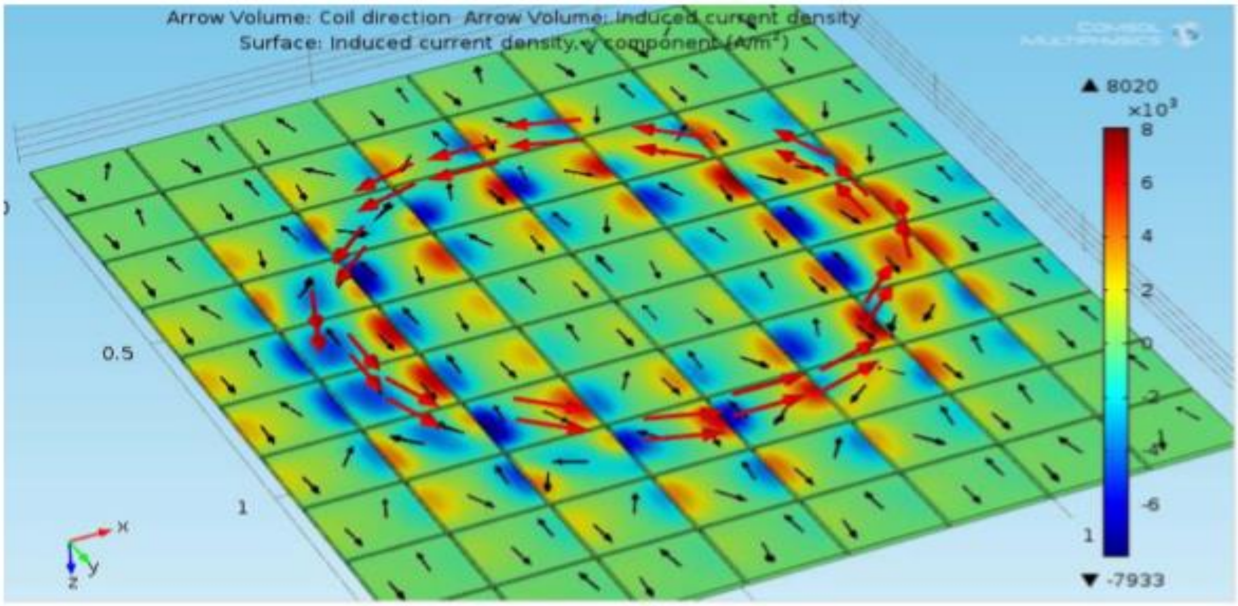


Figure 3.2: Eddy currents induced in the solar roads at 50Hz (Venugopal, et al., 2018).

Solar roads are always preferred to install in the emergency lane of the highway because of low occupancy and high energy utilization, which helps in reducing dynamic shading of the solar cells and avoids vicinity with the on road IPT charging. A Mosaic on-road space sharing design can be made instead of sandwiched structure, when dynamic IPT charging is not required for complete highway coverage *(Venugopal, et al., 2018)*.

Netherlands future highway case study

Figure 3.3 illustrates the future highway design with solar road, green energy, IPT and self-healing characteristics of A12 motorway in the Netherlands, test case. A12 highway is 165km and connects a city of Arnhem and the Hague in the Netherlands. To design this, a Nissan Leaf is used as reference consisting of 24 kW battery pack and it is assumed that the battery has 85% efficiency. Out of 165km, it is presumed that EV drives 10km both at starting and ending of the highway, 60km/h in the urban area and the remaining 145km at the speed of 120km/h. The speed of the EV is vice-versa to the power demanded by the EV to drive, linearly estimated as 5.6kW when driving at the speed of 60km/h and goes up to 24.1kW for 120km/h speed. Based on this the required energy for the Leaf to cover 165km is 31kWh, this value is higher that 24kWh capacity of Leaf even if it is assumed that EV begins at 100% SOC and end the journey at 0% SOC, which never occurs practically *(Venugopal, et al., 2018)*.

For safeguarding EVs to complete its journey without having a stop, IPT system is used to charge it. The objective is if an EV starts the journey with the 80% SOC, should complete the trip along A12 with at least 20% SOC. This corresponds to using in 24kWh × (80%-20%) × 85% = 12.2kWh of the EV battery at 85% round trip efficiency. The remining (31-12.2) = 18.8kWh must be supplied by the IPT system, to achieve this 50kW IPT system with 85% efficiency is used. The IPT system Is expected to be mounted in the highways busiest part over a length of 50km which is specified as A and B in the figure 3.3 to meet the energy demand. SOC of the battery along with the highway as EV drivers from the Hague to Arnhem is shown in the figure 3.4. With the use of IPT system, the EV covers the total distance of 165km with 20 to 25% of SOC lasting. In the absence of IPT system, SOC starts decreasing from 80% to zero by the time it crossed 96km. When the EV travels at the average speed of 120km/h in practice and finishes the journey with higher SOC. From this it illustrates the efficiency of on-road charging with IPT system *(Venugopal, et al., 2018).*

Figure 3.3: A12 highway between Den Haag and Arnhem with IPT system installed over two section- Part A for 20km and Part B for 30km (Venugopal, et al., 2018).

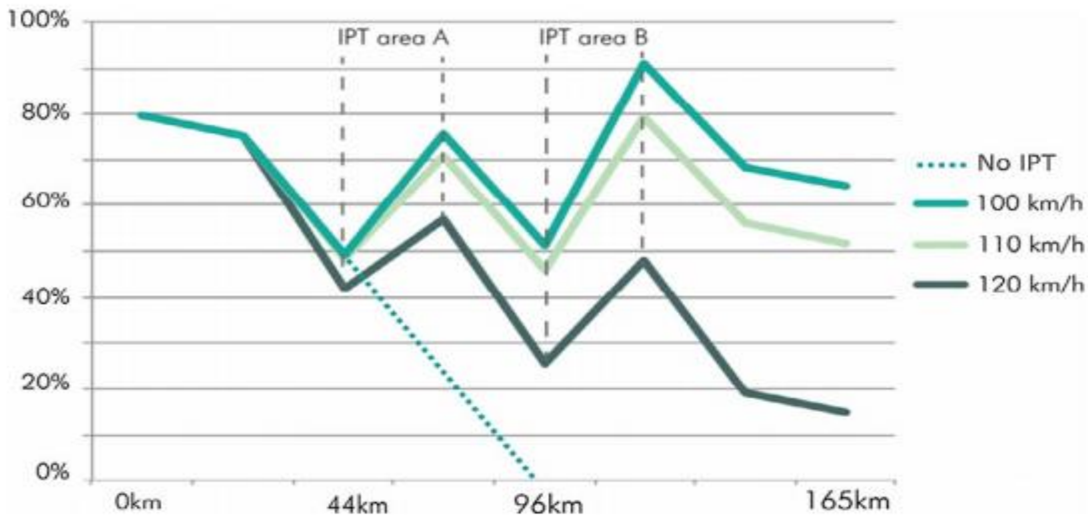


Figure 3.4: The SOC of the battery along the A12 highway for different driving speed. The average speed for urban driving remained the same for all three situations. A driving speed of 100km/his more energy efficient (Venugopal, et al., 2018).

3.5 Inductive Self-Healing Asphalt (IHA)

Porous asphalt concrete roads take over solid high graded asphalt concrete due to its water drainage and noise reduction. However, porous structures do not have durability of asphalt which causes premature raveling of the road. When asphalt concrete is exposed to large stress and strain, self-healing occurs by forming micro cracks in the material. The bulk material can be repaired and to regain its strength by rearranging the diffusion molecules from one face of the crack to another. In practice, when period of stress at ambient temperature, the self-healing process is very slow, but it increases with increase in temperature. Depending on the asphalt mixture and the damage heating asphalt (85°C) can achieve significant healing with a resting period of 3-6h (recovery 70-85 %). Therefore, heating system in the road allows the asphalt to use its healing property in less time without intruding the traffic. Heating can be done in different methods, but induction heating is the most effective because this heating will not contaminate the asphalt, provides excellent heat distribution inside the asphalt and can also control the amount of heat generated. Heating of the asphalt by induction method can be done when and only if it is conductive. Thus, by mixing additive like graphite or steel wool in the asphalt to induce eddy currents *(Venugopal, et al., 2018).*

3.5.1 Combining self-healing roads with IPT

For induction healing and inductive power transfer, IPT system uses induction coils and self-healing roads can be used. It is very important to add power density is essential for heating for specified area of self-healing asphalt. Combination of these two definite technologies brings various advantages and challenges. When the system functions at high power, drop in the power transfer and the efficiency at 85kHz can be a problem. This can cause unintentional asphalt heating and extra leakage in the system. The movement of cars impacts the batteries energy transition from a fixed charging pad on the surface of the ground *(Venugopal, et al., 2018).* For FEM analysis and lab-scale experiments, four studies exist, and they are thermal modelling of self-healing system, experimental verification, loss model of combined inductive system and numerical analysis. The way these two technologies can co-exist is based on the concept of sectional roads, the center of the road is subjected to less stress on an average. On the other side, the middle of the road where energy transfer through the energy system is necessary, standard asphalt can be paved. While sharing the infrastructure, energy transfer and healing are optimally used. Further research is carried out considering the material selection of IHA for asphalt roads wherein the healing process doesn't impact IPT while it serves IHA when required *(Venugopal, et al., 2018).*

Summarizing, the smart charging is the technology where charging can be controlled external. It allows EV to charge at varying capacities depending on load availability. The technology can also use sustainable energy and avoids peak load demand on the grid and excess power can be given back to the grid. Trials are going in Overijssel and Gelderland and in the cities of Groningen and Drenthe focusing on free choice of energy, which helps all energy companies to supply energy. Wireless inductive charging technology where charging can be done using induction plate with electromagnetic fields and has advantage of not using high voltage power cable. Experiments are carrying out by many companies in the city of Rotterdam. Both these technologies can be controlled with aid of an app. Solar roads is a Dutch innovation, integration of IPT with solar roads helps in using sustainable energy, excess energy is being supplied to signal lighting. Trials are made between the cities of Arnhem and the Hague using Nissan Leaf and has a maximum efficiency of 9.69%. Integration of IPT with self-healing asphalt posses' various advantages and challenges and needs further research. Both these technologies are still in experimental phase and uncertain for the availability for the consumer market.

4. CURRENT AND FUTURE POLICIES

This chapter explores the various policies regarding EVs and charging infrastructure. First the current policies are analyzed in the section 4.1 and future policies are analyzed to roll-out of charging infrastructure and EVs are discussed in the section 4.2.

4.1 Current Policies

In this section the current policies such as energy agreement, green deals, sustainable fuels vison, incentivizing market stimuli, incentivizing legislations and regulations and few other policies are analyzed.

4.2.1 Energy Agreement

It was implemented in the year 2013, acts as a base for sustainable energy, climate policy and future proof. The plan involved a large alliance of stakeholders with different backgrounds in government, NGO, and business. A few parties are FNV, NS, ANWB, MKB Nederland, Rijksoverheid, Natuur&Milieu and Greenpeace. The plan has both long-term and short-term agreements and goals *(Sociaal-Economische Raad, 2013).*

The main goals of the energy agreement are, reducing final energy use with 1.5% per year with an intermediate goal of saving 100 Petajoules of energy by the year 2020, increasing to 10% in 2020 and 16% in 2023 from renewable energy technologies. Creating full time jobs of at least 15,000. To include all significant disciplines and stakeholders, energy agreement is divided in plans for 10 pillars. One of the pillars is mobility and transport. The main aim of mobility and transport is to increase efficiency and sustainability. The aim is translated into several goals: Reduction in CO_2 emissions of 60% by 2050 in comparison to 1990 and the intermediate goal is reduction of 25M tons CO_2 in 2030. A vision on sustainable fuels for transport is developed by coalition which results in actual use of existing fuels. This depends on availability, emission reduction potential and alternatives for each modality *(Sociaal-Economische Raad, 2013).*

4.1.2 Green Deals

Several green deals were implemented by the Netherlands to stimulate the development of the public charging infrastructure. It is an agreement between the stakeholders and the government to minimize barriers of successful implementation of a sustainable initiative. The green deal covers energy, water, resources, climate, biodiversity, food, and buildings *(Rijksoverheid, 2016a).* The government can adjust regulation and law to minimize bureaucracy and bring related actors together to communicate in negotiations and help to explore the new market by enforcing regulations. In 2011, the first green deal on charging infrastructure was implemented. The green deal electric mobility was an agreement between the government, car sector organizations, NGOs and local governments *(RVO, 2016b).* This deal ensures the continuation of stimulation of EV sales, development of focus areas, Formula E-team, and public charging network. The government provided adequate freedom for startups on charging infrastructure with smart grid applications. It also results in the removal of barriers in law and regulations for charging infrastructure, permits for parking and environmental zones with limited access.

The next green deal was green deal infrastructure for mobility. The New Motion, in co-operation with Alliander, Foundation E-laad, several ministers and car manufacturers signed the green deal with the aim to develop large scale smart public charging network *(RVO, 2016b).* It provides charging service along with the capability to balance the grid with supply and charging. The New Motion installed 15,000 private, semi-public and public charging stations. The government pressurized the importance adequate authorization of public charging infrastructure to municipalities. This resulted in brochures for municipalities in 2012 and 2013, the first brochure informs the importance of stimulating EVs on municipal level and provide general data on electric vehicles and charging infrastructure *(Agentschap NL, 2012).* The second brochure provides answers for the municipalities to integrate charging infrastructure in public space. Slight participation is required for self-sufficient EV drivers as they charge and park in private. When an EV driver parks on the public parking space but chargers with a private charger, involvement is limited for setting up charging station and parking. The last case requires more municipal involvement: Public parking combined with public charging and the municipality can supply and maintain the charging stations and implement market model for public charging *(Agentschap NL, 2013*).

From 2015 public charging electric infrastructure of green deal includes ElaadNL, EvnetNL, grid operators, NKL and several government bodies. It is necessary to extend the development for charging infrastructure, to stimulate sales of EVs. Although, charging infrastructure are not cost effective yet irrespective of the supply and maintenance. Hence, the national government supplies 5.7 million Euros to municipalities for the realization of public charging infrastructure, with a maximum of 900 Euro per station in the first year, 600 and 300 Euros for second and final year *(RVO, 2016b).*

In the year 2016, the Green Deal Electric Mobility was signed, aims to extend the front runner role of the Netherlands and to bundle the events on EVs until 2020, so the market has matured and requires no support to grow. It incorporates establishing a consumer market next to the existing business market, improving charging infrastructure, initiate Living Lab for smart charging and electricity storage in EVs. This leads to 50% increase of EVs in newly sold passenger cars in 2025. Out of newly sold passenger vehicles 10% should have an electric drivetrain before 2020, so 75,000 individuals drive an EV including second hand. Reducing the uncertainty on the market for public charging is aim of national government *(RVO, 2016b).*

4.1.3 Sustainable Fuels Vision

In the year June 2014, sustainable fuels vision was presented as planned in the energy agreement. The authors describe the vision as an ambitious but realistic future for the Netherlands, which will make the Netherlands a front runner in sustainable mobility *(Ministerie van Infrastructuur en Milieu, 2014).* It describes improving the local environment, achieving green growth and the potential of sustainable fuels in CO2 emission and the vision is shared by stakeholders of the energy agreement. This vision focuses on the electric drivetrains, the most suitable fuels for passenger vehicles in 2050 will be electricity and hydrogen. The desired 60% CO2 reduction in 2050 will not be achieved without the implementation of EVs, since battery-powered EVs are the most energy-efficient type transport *(Ministerie van Infrastructuur en Milieu, 2014).* The solar and wind energy is utilized as an energy carrier for electric and hydrogen drivetrains is another advantage. Finally, the electric drivetrains in passenger transport is also the availability of biomass for biofuels and renewable gas may be limited as a result of competition with other segments. The liquid and gaseous (bio)fuels are reserved for transport modalities which cannot benefit from these from aviation, logistics and shipping *(Ministerie van Infrastructuur en Milieu, 2014).*

According to the sustainable fuel vision, approximately 700,000 BEVs and 1,570,000 PHEVs by 2030 and it will increase to 7,700,000 BEVs and 3,000,000 PHEVs by 2050 with few barriers that needs to be addressed. These barriers can be balanced by set of Green Deals, by minimizing the investment costs and a positive business care for public charging infrastructure. Implementing a law of Right to a Charging Point is another measure, so that EV driver can demand a [public charging point closer to their house. This will increase EV demand among people with private parking space, and a well-developed fast charging stations in parallel with the conventional charging stations minimizes range anxiety *(De Tafel Wegvervoer Duurzaam Elektrisch, 2014).* The time period for a proposed sustainable fuels vision range between 2015 to 2030.

4.1.4 Incentivizing Market Stimuli

Stimulus measures including price incentives and schemes are done on purpose to encourage market of the charging infrastructure to develop further. When electric vehicle is purchased, some of the car manufacturers offers home charging point, which is making significant contribution to the growth of charging infrastructure for EVs *(The Ministry of Economic Affairs, 2017).* The central government is providing a various market stimuli which are discussed further below.

The central government's contribution to 'Publicly Accessible Electric Charging Infrastructure', is also been a part of Green Deal, where central government provided a total amount of 5.7 million Euros for both local and regional authorities (municipality, province or region) to implement charging networks for the period 2016 to 2018 and 10,000 public charging points are expected to implement. The central government contributes to vitalize the rollout of public charging infrastructure, which meets the preconditions set. At first, both local and regional authorities must manifest that they are also making equal financial contribution by calling tenders or through another channel and that they get assurance from the private parties for their contribution in rollout of public charging infrastructure *(The Ministry of Economic Affairs, 2017).*

Environmental Investment Tax Scheme (MIA) for charging infrastructure, facilitates businesses to make investments in environmentally friendly technologies and the businesses also get benefits to their tax positions. The MIA with VAMIL (Random Depreciation of Environmental Investments) tax schemes helps in encouraging environmentally friendly operating assets. There are two strategies covered by the MIA to ensure private charging station on company's own site for lease cars. First one, when the total investment is less than 50,000 Euros for a 'car and charging point on a company's own site', then the whole amount is eligible for the MIA for the lease company. Secondly, when the total investment is less than 50,000 Euros in the case of a private lease where the lease company provides a car and a charging point to the customer, then the entire amount is entitled to the MIA for the lease company *(The Ministry of Economic Affairs, 2017).*

Businesses may also entitle to the MIA. For businesses, an application maybe made precisely if the investment is higher than 2,500 Euros for charging point or for an electric car with the total investment less than 50,000. The annual amendment of the Environmental List means to respond swiftly to new sustainable technologies. This idea is to raise awareness of this scheme for target group's by giving more attention to communications regarding the tools already available *(The Ministry of Economic Affairs, 2017).*

Temporarily reduced energy tax rate for charging points, the energy tax rate is reduced by the government for public charging stations in response to Van Weyenberg/Grashoff motion for the period 2017-2020. This helps charging station operators to pay less tax for each kWh supplied. This tax reduction is temporary but may improves the business case for a public charging stations *(The Ministry of Economic Affairs, 2017).*

4.1.5 Incentivizing Legislation and Regulations

The central government is working on incentivizing legislation and regulations to promote transition in E-mobility and energy transition. As described in section 2.2.1, the principle framework for the market has been created with the help of market model. Along with the implementation of the European Deployment of Alternative Fuels Infrastructure Directive, the Dutch government is also working on the enabling conditions which allows uniform recharging in every part of the EU *(The Ministry of Economic Affairs, 2017).* Incentivizing legislations and regulations are discussed further below.

Implementation of the EU Deployment of Alternative Fuels Infrastructure, as they play a vital role in standardization of charging infrastructure. The main purpose of this directive is to strengthen of the market by implementing communal technical specification for alternative fuels infrastructure in the EU and as a result to encourage the deployment of charging infrastructure for E-mobility. This helps EV owners to charge their vehicles all around the EU. The directive sets requirements for refueling and recharge points for LNG, CNG, hydrogen and electricity. Standardization helps interoperability and consumers' interests. This is uncomplicated for both the consumers and business community as in the longer term, economies of scale will guarantee a cost-effective rollout strategy. The directive is being implemented by means of decree and a policy framework. Its implementation covers provision of information for the consumers as well as technical standards relating to sockets and connectors. The technical requirements for EVs apply to the public charging stations and will be specified in detail in the explanatory notes to the decree *(The Ministry of Economic Affairs, 2017).*

Incorporating solutions for obstacles in legislations and regulations, as decided in the Electric Transport Green Deal 2016-2020. The central government is actively identifying and incorporating solutions for regulations and legislations for barricading in upliftment of EVs. A wide-ranging process focused at identifying obstacles including charging infrastructure are started. The NKL and Formula E-Team working as a sounding-board in problem solving process by collecting information from market players *(The Ministry of Economic Affairs, 2017).*

Charging infrastructure and the built environment for the private owners of EVs are excessively dependent on access to charging points at blocks of business premises, flats and office. EV users get enough charging points were made sure by the project developers and managers of that buildings, considerations are given to some extent with current regulations, like the Buildings Decree and apartment rights which are acceptable mechanism for this purpose. The Building Directive for EU energy performance is being revised and the revised version may have requirements regarding the minimum number of charging points at alteration of existing building and new buildings parking spaces. From this it seems practical to spare more attention to charging infrastructure for E-mobility in the built environment and since it involves relatively small investments for installing new charging stations *(The Ministry of Economic Affairs, 2017).*

The Road Transport report by the Social and Economic Council of the Netherlands (SER) Fuel Vision states that people living in a flat with Owners' Association (VVE) are allocated space in the collective parking space. The Association of Netherlands Municipalities (VNG) noticed that it knows many situations where EV owner must take care of the charging costs and they don't get any support from the Owners' Association. The sustainable Electric Road Transport report and the Association of the Netherlands Municipalities recommend that every EV owner is given right to a charging point *(The Ministry of Economic Affairs, 2017).*

Amendments to the regulatory framework to make the electricity system more flexible, is an important measure which needs to be taken to make better the ductility of the electrical system, based on the data from the stakeholders, were fleshed out in the Energy Agenda. They are dynamic supply prices for low-volume users, the aggregator's role, and creating greater flexibility by adjusting the tariff structure *(The Ministry of Economic Affairs, 2017).*

4.1.6 Other Policies

The final national policy deals with fast charging stations. The Netherlands government first assumed that fast charging stations with existing fuel stations and restaurants could be integrated together as they already operate service areas. Though this was the easiest solution, but interest was low as number of EVs were limited. This is the reason the Dutch government changed the policy in 20^{th} December 2011, which permits new market players to bid on exception for fast charging stations. Six new parties got exceptions to provide electricity for 459 connections at 249 service stations and Fastned emerged as a major player with 55 stations all over the country. The Netherlands is the first European country to develop a nationwide fast charging network *(Fastned, 2015).*

In parallel to the national government, local government also set up ambitions on E-mobility and implemented policies. The region Amsterdam collaborated with the company Metropole Region Amsterdam Electric (MRA Electric) to uptake EV sales by expanding the charging networks, by cooperation and knowledge sharing. MRA Electric played a role of organizing a public procurement for charging stations allowing all municipalities in the region to join the procurement. Installation, maintenance and exploitation of charging stations is managed by a market player. Since the business case was negative, the regional governments provided financial support to the procurement. The EU, the national government and market parties invested. Hence, only 1000 Euros per charging stations were charged to individual municipalities *(MRA Electric, 2016).*

The municipality of Rotterdam changes its responsibility to facilitate the expansion of public charging infrastructure from stimulating and wrote a report on that. Hence, earlier subsidies are eliminated. For a procurement, limited budget is allocated for compensating the financial gap until 2018. This explains a switch to demand driven infrastructure: when there is no substitute in a 250-meter radius and expected charging, demand is over 2000 kWh per year, then EV owner an apply public charging stations in their area. They introduced a fixed rate for parking on a charging spot, nevertheless the car is charging or not. This is to stimulate EV owners disconnect their vehicle when it is fully charged. Rotterdam examined the possibility to install ‘charging squares’, with a large density of chargers, where demand for charging an EV is high and increasing (*Gemeente, Rotterdam,2015).*

The municipality of Utrecht structured an action plan on Sustainable Transport. The main goal of this action plan is to enhance sustainability in all kinds of transport by increasing E-mobility. Thus, Utrecht stimulates EVs for both light and heavy transport, increasing the chain of public charging infrastructure, tweaking efficient use of charging network, and providing incentives to private charging stations at businesses and citizens. It also aims at realization of 400 public charging stations in 2020 *(Gemeente Utrecht, 2015).*

The subsidy schemes for the EV market may stop, once the EV market rise and reaches the early majority share. For example, addition tax (bijtelling) for vehicles whose CO2 emission is in between 1 and 50 grams per kilometer, i.e. PHEVs. Their addition tax will rise which is equal to the internal combustion engine vehicles. Only exception is given to zero-emission vehicles with the 22 percentage is shown in the table 4.1. PHEVs had other tax exemptions like BPM and MRB, are also given the same as conventional cars. By taking these measures the Dutch government expect to stimulate BEVs and fix the faults in the current system *(Rijksoverheid, 2015).*

	2016	2017	2018	2019	2020
Zero-emission	4%	4%	4%	4%	4%
PHEV (1-50 gram/km)	15%	17%	19%	22%	22%
Efficient (51-106 gram/km)	21%	22%	22%	22%	22%
Other (>106 gram/km)	25%	22%	22%	22%	22%

Table 4.1: Changes in additional tax (bijtelling) from 2016 to 2020 (Rijksoverheid, 2015).

The market of the PHEVs is evolving, but there is no positive business case for public charging infrastructure, the one main issue is tax on electricity. The Ministry of Finance claims that tax costs per kilometer for EVs are lower than internal combustion vehicles. The calculation of the tax is shown in table 4.2 *(Ministerie van Financiën, 2016).* The amount of tax rate on electricity supplied is dissected in steps. The tax for the first step 10,000 kWh is 0.1007 €. the tax rate from 10,001 to 50,000 kWh is 0.04996 €. For the next step from 50,001 to 10 million kWh is 0.01331 €. The tax rate for individuals whose electricity consumption over 10 million kWh is 0.00107 € and for business the rate is 0.00053 €. A public charging station has its own electricity grid connection and considered within the first step. Hence the tax rate for public charging station is very high *(Belastingdienst, 2016).*

Fuel	Efficiency	Unit	Tax rate	Unit	Costs per km
Electricity	18	kWh / 100 km	€ 0.101	€ / kWh	€ 0.018
Gasoline	6.33	Litre / 100 km	€ 0.770	€ / litre	€ 0.049
Diesel	5.66	Litre / 100 km	€ 0.484	€ / litre	€ 0.027
LPG	7.60	Litre / 100 km	€ 0.195	€ / litre	€ 0.015

Table 4.2: The tax costs per kilometer for EVs and internal combustion engine vehicles (Ministerie van Financiën, 2016).

From the above table 4.2 it shows that EVs has less tax per kilometer than the internal combustion engine vehicles. However, if tax rate per unit of energy is calculated, it clearly indicates that tax rate on electricity is higher. Per MJ of electricity shows that the tax rate is 117% greater than per MJ of gasoline, is shown in the table 4.3 below. This higher percentage is obvious, since other fuels like diesel and LPG are more efficient and has lower tax than gasoline in terms of CO2 emissions per kilometer and have a lower tax of 54 percent for diesel and 29 percent for LPG. The EVs have high fuel efficiency and require less energy input per kilometer which makes them less in terms of costs per kilometer *(Ministerie van Financiën, 2016).*

Fuel	Tax rate	Conversion to MJ	Tax rate (€ / MJ)	Relative to gasoline
Electricity	€ 0.101 / kWh	1 kWh = 3.6 MJ	0.028	117 %
Gasoline	€ 0.770 / litre	1 litre = 32 MJ	0.024	100 %
Diesel	€ 0.484 / litre	1 litre = 36 MJ	0.013	54 %
LPG	€ 0.195 / litre	1 litre = 27 MJ	0.007	29 %

Table 4.3: The tax rate per unit of energy for electricity, gasoline, diesel and LPG (Ministerie van Financiën, 2016).

The MSPs must pay high tax rate for electricity supplied to the charging networks which is paid by the consumers, leading to higher prices and limiting demand. The government implemented the new regulation which reduced half the tax rate on public charging infrastructure during the years 2017 to 2020 to stimulate public charging infrastructure. This is done by applying this regulation in the second step to public charging infrastructure. This measure is going to stop in the year 2020, because the government assumes that no stimulation is required for the roll out of E-mobility after 2020 *(Ministerie van Financiën, 2016).*

Another most important policy measure for charging infrastructure is the right to a charging station. This policy is one of the proposed policies in sustainable fuels vision. This stimulates governments, businesses and building owners to install charging stations on their own property. When an EV driver request to install a public charging station, the officials responsible for public space includes road construction and maintenance should implement the charging stations. This measure is implemented from the year 2015 to 2020 *(De Tafel Wegvervoer Duurzaam Elektrisch, 2014).*

4.2 Future Policies

This section explores future policies agreed in the climate agreement which are national charging infrastructure agenda and financial and tax incentives for EVs are discussed in detail below.

4.2.1 National Charging Infrastructure Agenda

The national government, municipalities, provinces, network managers, Dutch businesses and industry association came together to draft a National Charging Infrastructure Agenda. The agreement made in this agenda is to improve charging stations and charging capacity for increasing amount of EVs. To implement this, agenda is divided into regional mobility plans in deliberation with municipalities and provinces. These plans are made to meet local needs for charging infrastructure *(Climate Agreement, 2019).*

To meet the demand for 2030, 1.8 million public, semi-public, and private charging stations must be placed. The Netherlands Organization for Applied Scientific Research (TNO) conducted a survey and realized that 18,600 charging stations are needed for vans and 7,400 for lorries to meet the demand in 2030, which is almost 700 stations must be installed every day at the final stage. This is achieved only by means of clear agreements and cooperation between all parties. For construction and operation of regular charging stations there should not be any financial public funding which an important principle is, drawn when making the agenda. This agreement is a part of climate agreement *(Climate Agreement, 2019).* The national charging infrastructure agenda focus on following below.

Setting up basic conditions and fastening the process in improving the public charging infrastructure for EVs. Establishing and strengthening cooperation regions which helps municipalities to draft and implement policies. Implanting commitments for rolling out charging infrastructure involving Regional Energy Strategy (RES), the environment plan and the environmental strategy. Placement policy adoption which will be improved every two years; Providing tools and guidelines to regions and municipalities. In addition to roll-out, agreement also aims at improving private charging infrastructure *(Climate Agreement, 2019).*

To guarantee a steady electricity network, the smart charging will be used, in which renewable energy can be used and it benefits EV drivers, which includes through, establishing and optimizing market models for smart charging. Difficulties for the smart charging in the smart charging will be translated into new regulations by legislation and experimentations. In parallel to bidirectional charging, difficulties in the operation of energy tax is done by investigation from which solution will be sought. Developing new architecture alternatives for smart charging. The digital communication between EVs and charging infrastructure will be made simple *(Climate Agreement, 2019).*

Improving charging infrastructure for the future by giving more attention to innovation, which includes through, integrating the innovation challenges ensuing from the national charging infrastructure agenda in knowledge and innovation agenda for mobility. Assuring on the implementation of programmes and projects follow on from the national charging infrastructure agenda and liberal to experiment rooted within laws and regulations essential for demos *(Climate Agreement, 2019).*

The recognition of charging infrastructure for urban logistics, enables combined development and growth of electric mobility in the transport machinery and E-mobility of goods which includes, research in the charging infrastructure for mobile machinery. Understanding and responding to the rising requirements for the use of heavy goods zero-emission vehicles and requires solutions for new charging infrastructure with large capacity, hence this will have higher impacts on the energy grid. Evaluation of charging needs and charging behavior in respect of urban logistics, which is to determine ideal charging sites and possible need of strengthening the energy grid to permit to incorporate more zero-emission vehicles in urban logistics. Analyzation of the vital charging infrastructure for inland shipping *(Climate Agreement, 2019).*

The RVO will frame a programme to keep track the developments of national charging infrastructure agenda implementations. The national government will appoint a piloting committee in addition to the RVO, which includes delegates from the Formula E-Team, the Ministry of Infrastructure and Water Management, the VNG, the ElaadNL, and the association of Provincial Authorities *(Climate Agreement, 2019).*

4.2.2 Financial and Tax Incentives

The Dutch government focusing on EVs to make it more affordable and attractive to everyone in long term, which government looking forward to minimizing the need for per-car incentive. Although, in transition to EVs by providing incentive which means the government gets less income from the excise duty. The integration of tax on ownership and tax on fossil fuels is the current motor vehicle tax system. The concept of E-mobility is becoming more socially established, hence long-term approach to motor vehicle tax system is very crucial. The new system also must make sure that there should be reasonable contribution towards the costs who uses the charging infrastructure. This system also has advantage of reducing emissions and traffic congestions. To encourage the second-hand market of EVs to public, the government will develop a strategy for reimbursement of battery guarantees or purchase subsidies and charge credit which helps public to afford second-hand EVs *(Climate Agreement, 2019).*

Financial and tax support for zero-emission cars. The table 4.4 gives overview information about incentives per instrument from 2021- 2030, this is initiated by the government to support financially for zero-emission vehicles. Till the year 2024, the zero-emission vehicles will be remained exempted from the motorcycle tax and the private motor vehicle tax. However, motorists must pay a fixed amount of 360 Euros from the year 2025. Zero-emission vehicles will be exempted from the national component of the motor vehicle tax until 2025. But, in 2025 they must pay 25% tax. This is only for BEVs and PHEVs must pay tax with a correction factor because of its heavy weight in respect of conventional fuel cars. For private zero-emission vehicles, a declining cost-efficiency purchase subsidy will be introduced, which starts from 2021 at PM Euros per vehicle and later it will reduce, given anticipated augmented presence on the market for affordable models of EVs. Additional tax at reduced rate is applied over 50,000€ maximum of the catalogue price for EVs, this will be reduced to 45,000€ in 2020 and further to 40,000€ in 2021.

This trend starts at 8% in 2020 and will be increased to 12% in 2021 and to 16% in 2022. For incentivizing second-hand zero-emission vehicles, measures like providing charging credit to private peoples, giving cost-effective subsidy to lower segment electric cars, reimbursing the constructional costs for charging stations at home and/or a battery leasing scheme or a battery warranty will be developed in discussion with the sectors and these measures are between 2021 and 2024, for this €100 million will be reserved *(Climate Agreement, 2019).*

Incentive policy	2020	2021	2022	2023	2024	2025	2026*	2027*	2028*	2029*	2030*
Motor vehicle tax fixed rate, electric	0	0	0	0	0	360	360	360	360	360	360
Motor vehicle tax FCEV/EV, electric	0%	0%	0%	0%	0%	25%	100%	100%	100%	100%	100%
Additional tax	8%	12%	16%	16%	16%	17%	22%	22%	22%	22%	22%
Additional tax cap	45000	40000	40000	40000	40000	40000	N/A	N/A	N/A	N/A	N/A
Private subsidy	The series will be determined in due course to ensure the most effective implementation						0	0	0	0	0
Linear reduction for private subsidy	40k – 60k	40k – 60k	40k – 60k	40k – 60k	40k – 60k	40k – 60k	0	0	0	0	0

Table 4.4: Overview of incentives per instrument, 2021-2030 (Climate Agreement, 2019).

4.2.2.1 Incentivizing with the "Hand on the tap"

It has been agreed that an assessment will be carried out in 2024. This review is carried out to know the possible developments in the vehicle market to recognize those policies and measures which is needed after 2025 to attain the target of 100% zero-emission vehicles. To avoid over-incentivization, the incentives will be evaluated annually to keep a "hand on top" *(Climate Agreement, 2019, p65, para5).* From this it is possible for both upward and downward adjustment of providing incentives. The policies agreed in the "hand on tap" principle are financial control, where incentive packages can be adjusted based on the development whether it is faster or slower than the agreed financial framework. Non-tax incentives, a subsidy ceiling ("when it's gone, it's gone") applies to both second-hand market (100 million) and purchase subsidy for private individuals and hence, the annual financial ceiling for these measures cannot be exceeded *(Climate Agreement, 2019 p66, para1).* Tax incentives (motor vehicle tax, additional tax liability, private motor vehicle and motorcycle tax), the higher or lower losses will rise if the EV sales is higher or lower than predicted in the year. In the coming years, if structural variation from the trajectory are expected then this situation can be calibrated in the year t+1. This is done in both ways by maintaining EV sales and preventing losses in the coming years. Frequency of evaluations will be carried out in addition to the annual review. This review will be submitted to the house and any amendments. The comprehensive evaluations will be carried out as 2022/2023 interim evaluation, 2023/2024 2027/2028 interim evaluation and in 2030 final evaluation of the climate agreement *(Climate Agreement, 2019).*

4.2.2.2 Cover for any losses of revenue and additional expenses

The national government and the Formula E-Team agreed with respect to coverage are zero-emission vehicles must pay private motor vehicle tax and motorcycle tax with fixed amount of 360 Euros per vehicle. The excise duty on diesel will be raised by 1 cent from 2021 to 2022 and again 1 cent is increased as of 2023; the discounts for motor vehicle tax for vans are slowly decreased, so there will be rise of 2 Euros per month from 2021 to 2024 *(Climate Agreement, 2019).* This overview is shown in the table 4.5.

Coverage policy	2020	2021	2022	2023	2024	2025	2026*	2027*	2028*	2029*	2030*
Motor vehicle tax increase per year per van	0	24	48	72	96	72	72	72	72	72	72
Diesel excise duty	0	1	1	2	2	2	2	2	2	2	2

Table 4.5: Overview of coverage per instrument from 2021 to 2030 (Climate Agreement, 2019).

4.2.2.3 Compensation for provinces regarding electric transport incentives (Excise duty losses for provinces)

According to the Motor Vehicles Memorandum II, until 2024 electric passenger cars will be exempted from the motor vehicle tax and surcharges. As per this proposal EVs will also have to motor vehicle tax (depending on potential changes to the system) from the year 2025. The impacts of the electric vehicle incentive package in the climate agreement, creates different definition between the national government and the IPO (Association of Provincial Authorities). The IPO states provinces will lose revenue due to zero traffic (provinces may not impose motor vehicle tax on EVs) for each EV sold. This leads to smaller revenue which has an impact on open management, these losses must be compensated by the provinces. Based on current situation, the national government states that increase in conventional cars confirms that total annual revenue from surcharges in the period 2021 to 2024 will not considerably decline with respect to the year 2020. So, the national government believes there will be no loss in the revenue for the provinces. The provinces and the national government have a common interest in ensuring effective monitoring of the development of electric transport in the years to come. The national government will be responsible for maintaining an identical or otherwise comparable individual tax area in terms of impact. This type of taxation should ensure that the open management of the provinces will remain fully intact *(Climate Agreement, 2019).*

Review and adaptive planning towards zero-emissions new cars by 2030. The parties involved in this agreed that the uncertainty after 2025 is substantial, thus the government will go with pay-as-you-go options and included in the proposed tax review system for 2025. Pay-as-you-go options are a per-km pricing system for EVs with no variation to the current system for conventional cars. except for a rush hour charge, time and location-specific tax is given to all the vehicles. Emissions, specific-location and time tax for all the vehicles *(Climate Agreement, 2019).*

Summarizing, to stimulate public charging infrastructure and to reduce costs for installing new networks it is very important to formulate policies, for this the government set up several green deals as agreed in the energy agreement. It helps in improving charging infrastructure and consumer market, it is expected to increase 50% in 2025. The government also started sustainable fuel vision which is a part of energy agreement to promote sustainable mobility and made right to a charging points helps EV drivers to demand charging stations at their near place. Market model is developed, helps the market players to install a greater number of charging stations. Incentivizing market stimuli scheme provides tax reduction on energy to encourage charging infrastructure which helps CPOs to pay less tax on each kWh of electricity used. Environmental investment scheme encourages companies to invest in environment friendly technologies from which they get tax benefits. Incorporating solutions in legislations and regulations for charging infrastructure helps EV drivers to recharge their vehicles in every part of the EU. Implementation of the EU deployment of alternative fuels infrastructure strengthens the market which is also cost-effective strategy and set technical standards for connectors. Integrating restaurants and fuel stations with fast charging stations will also increase the numbers. Municipalities like Rotterdam, Utrecht and Amsterdam made own policies in addition to the national policies to stimulate public charging infrastructure. The Netherland is the only country to provide nationwide fast charging network in the world. The national government reduced the half of the tax on electricity till 2020 which is a positive business case towards charging infrastructure.

For the future policies, the National Charging Infrastructure Agenda is a part of climate agreement to meet the demand of charging infrastructure for 2030. It is achieved only with clear agreements and cooperation's by the stakeholders, where RVO monitors the implementation of policies agreed in the agenda. It helps in formulating new policies, innovations, developing smart charging and increasing E-mobility in urban logistics. Financial and tax incentives help in providing incentives for Zero-emission vehicles, second-hand EVs to make it more affordable and attractive. Tax exemptions will be valid until the year 2024, after that they must pay 25% tax, but the PHEVs must pay tax with a correction factor due to its weight. To avoid over incentivization, hand on tap is introduced where incentives are evaluated every year and adopting to the market development. Loss of revenues and additional expenses due to incentives must be compensated by the provinces.

5. CONCLUSION

To reduce carbon emissions to mitigate climate change, transition to the electric vehicles is one of the options. This thesis is performed to deliver the requirements of charging infrastructure to 1.7 million EVs in the Netherlands in 2030. Based on the research work the following results have been obtained. Li-ion battery is used in most of EVs in the Netherlands due to its high specific energy, high efficiency and life cycle, the future battery technologies like Lithium Sulphur and Lithium air will have high specific energy and efficiency than the Li-ion batteries. DC fast charging helps in charging EV to 80% within 20 minutes but the number of fast charging in the Netherlands is still lagging. Mode 4 charging technique has a power to deliver DC at 50 to 175 kW. Type 2 connector is used to charge an EV which is authorized by the EU for charging < 22kW. Combined charging system connector is suitable for high power fast charging of EVs. There are many organizations involved in the field of charging infrastructure, the Ministry of Economic Affairs makes legislations to stimulate green growth and entrepreneurs in the field of public charging infrastructure. The Ministry of Infrastructure and Environment formulates and inspects laws and policies related to EVs and charging infrastructure. The Municipalities implement the policies made by the central government and provides public charging infrastructure. ElaadNL facilitates innovative projects and knowledge exchange between the companies to reduce cost of charging infrastructure. The market model ensures the freedom of choice, the government encourage small and medium scale industries to start a process by helping them to make it easier. The number of new registering EVs are increasing, but still lagging in the market share. Technological performance is analyzed using KPIs to know the performance of the existing charging stations based on the location. Depending on the maximum and minimum threshold occupancy rate different color codes were used to analyze performance. Detection of charging infrastructure bottlenecks is done by Using vulnerability tool and charge classification tool.

To uptake EV market to next standard the RVO is continuously conducting research in smart charging. The smart charging is the technology where charging can be controlled external. It allows EV to charge at varying capacities depending on load availability. The technology can also able to use sustainable energy and avoids peak load demand on the grid and excess power can be given back to the grid. Trials are going in Overijssel and Gelderland and in the cities of Groningen and Drenthe focusing on free choice of energy, which helps all energy companies to supply energy. Wireless inductive charging technology where charging can be done using induction plate with electromagnetic fields and has advantage of not using high voltage power cable. And not all EVs are designed to use this technology and currently using only in Formula-cars Experiments are carrying out by many companies in the city of Rotterdam. Both these technologies can be controlled with aid of an app. Solar roads is a Dutch innovation, integration of IPT with solar roads helps in using sustainable energy, excess energy is being supplied to signal lighting. Trials are made between the cities of Arnhem and the Hague using Nissan Leaf and has a maximum efficiency of 9.69%. Integration of IPT with self-healing asphalt posses' various advantages and challenges and needs further research. Both these technologies are still in experimental phase and uncertain for the availability for the consumer market.

To stimulate public charging infrastructure and to reduce costs for installing new networks it is very important to formulate policies, for the government set up several green deals as agreed in the energy agreement. It helps in improving charging infrastructure and consumer market, it is expected to increase 50% in 2025. The government also started sustainable fuel vision which is a part of energy agreement to promote sustainable mobility and made right to a charging points helps EV drivers to demand charging stations at their near place. Market model is developed, helps the market players to install a greater number of charging stations. Incentivizing market stimuli scheme provides tax reduction on energy to encourage charging infrastructure which helps CPOs to pay less tax on each kWh of electricity used. Environmental investment scheme encourages companies to invest in environment friendly technologies from which they get tax benefits. Incorporating solutions in legislations and regulations for charging infrastructure helps EV drivers to recharge their vehicles in every part of the EU. Implementation of the EU deployment of alternative fuels infrastructure strengthens the market which is also cost-effective strategy and set technical standards for connectors. Integrating restaurants and fuel stations with fast charging stations will also increase the numbers. Municipalities like Rotterdam, Utrecht and Amsterdam made own policies in addition to the national policies to stimulate public charging infrastructure. The Netherland is the only country to provide nationwide fast charging network in the world. The national government reduced the half of the tax on electricity till 2020 which is a positive business case towards charging infrastructure.

For the future policies, the government and number of parties came up with the climate agreement. The National Charging Infrastructure Agenda is a part of climate agreement to meet the demand of charging infrastructure for 2030. It is achieved only with clear agreements and cooperation's by the stakeholders, where RVO monitors the implementation of policies agreed in the agenda. It helps in formulating new policies, innovations, developing smart charging and increasing E-mobility in urban logistics. Financial and tax incentives help in providing incentives for Zero-emission vehicles, second-hand EVs to make it more affordable and attractive. Tax exemptions will be valid until the year 2024, after that they must pay 25% tax, but the PHEVs must pay tax with a correction factor due to its weight. To avoid over incentivization, hand on tap is introduced where incentives are evaluated every year and adopting to the market development. Loss of revenues and additional expenses due to incentives must be compensated by the provinces.

Overall, the study has identified the current technologies, organizations involved, technological performance. Then, it has identified future technological innovations. Furthermore, current and future policies are recognized for strengthening the charging infrastructure for promoting E-mobility in the Netherlands. Thus, the research has been able to achieve desired objective and has contributed to obtain knowledge about charging infrastructure in the Netherlands. Lastly, charging infrastructure helps in promoting sustainable transport system and ++it contributes to reduce greenhouse gas emission and mitigates climate change.

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