ELECTRIFICATION OF NORWEGIAN TRANSPORTATION VIA INCREASED DIFFUSION AND UTILIZATION OF FAST EV CHARGING TECHNOLOGY:

A TIS-analysis of the Norwegian fast EV charging station network

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ABSTRACT

10 years ago, use of electrification technology such as EVs and fast EV charging was arguably non-existent. However, rapid adoption, diffusion and utilization of EVs on the basis of changes in values, goals and aspirations related to the global climate, combined with sufficient and favorable premises and incentives, has seemingly led to a pertinent need for access to fast EV charging technology to address the final hurdle of massive EV adoption in Norway.

Fast EV charging technology is generally made available through development and commercialization of publicly available charging stations by various charging point operators (CPOs). However, the process of developing and operating fast EV charging stations is challenging and of a systemic nature. Furthermore, the process of intensifying electrification of the Norwegian transportation sector is currently facing several complex and system-based barriers and challenges. Additionally, this emerging technology is to a large extent being diffused and utilized within an incumbent regime-context in Norway.

The purpose of this qualitative case study is to increase understanding of the technological innovation system (TIS) of which is responsible of systemically diffusing fast EV charging technology, by making it increasingly available, utilized and commercial through fast EV charging stations. Increasing the understanding of this focal TIS can be undertaken by conceptualizing this specific system within theoretical and analytical frameworks of innovation. Including concepts such as the TIS- and MLP-approaches. By applying a qualitative methodology together with the concept of a system-lens, an analysis and discussion of this focal TIS can be conducted to be able to concretize challenges and barriers in addition to drivers and positively influencing aspects. Once concretized, these influencing aspects of the focal TIS can be addressed by for example reducing or removing barriers, while at the same time enforce and creating drivers to improve the functionality of the system.

Findings suggest that the Norwegian fast EV charging TIS is experiencing several detrimental barriers related to further development within aspects such as geographical context, legitimacy and governmental engagement. On the other hand, examples of strong functionality is also found within the system related to drivers such as global and national political pressure, changes in values, general advocacy as well as significant growth and development of premise providing artifacts such as EVs.

ABBREVIATIONS AND GLOSSARY

BEV - Battery electric vehicle

CPO – Charging point operator

3CPO – Third party charging point operator

EV – Electric vehicle

PHEV - Plug-in hybrid electric vehicle

FCEV - Fuel cell electric vehicle

ZEV - Zero emission vehicle

ICEV - Internal combustion engine vehicle

RET - Renewable energy technologies

TIS - Technological innovation system

SI - System of innovation

MLP - The multi-level perspective

SOE - State-owned enterprise

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1. INTRODUCTION: A GREEN TRANSITION WITHIN THE NORWEGIAN TRANSPORTATION SECTOR

Realization of a global climate crisis has gradually become very evident and at last, globally recognized and accepted as a challenge that faces the planet as a whole. A fact emphasized by the agreed upon Paris Climate Agreement in 2015, where 195 countries unanimously agreed to collectively combat climate change and adapt to its effects (UNFCCC, 2020). Consequently, The European Union (EU) has committed to reduce its emissions by at least 40 % by 2030 (EU, 2020). A commitment which embodies significant political influence since The EU serves as a premise provider as well as an institutional source of *soft infrastructure*[1] for the Norwegian government's laws and regulations.

As a consequence of EUs political influence and commitments, Norway looks inwards to investigate how to achieve a 40 % emission reduction. This commitment poses a challenge for Norway in particular since much of the Norwegian economy, particularly the industry- and residential sectors, mostly consumes locally produced green hydro energy. Leaving the Norwegian economy already relatively electrified and with considerably low emissions. Thus, the transportation sector is left as a logical alternative for increased climate efforts to meet internationally agreed upon political commitments.

As a considerable frontrunner of electrification of transportation, Norway already sets the standard for relative EV adoption globally. Although the impact of a country with 5,5 million inhabitants is arguably limited in terms of effects on the global climate, understanding the case of the diffusion and utilization of cleantech such as EV – and EV charging technology, in combination with renewable energy technologies (RETs) such as local, clean and cheap hydro energy, is a powerful lesson. Diffusion and utilization of this combination also serves as a proof of concept and platform for learning to the rest of the world. Enabling initial knowledge development within aspects such as technical-, commercial and institutional know-how. Knowledge which may contribute to establishment of initial markets through entrepreneurial experimentation. A necessary starting point for commercially viable opportunities to occur. Opportunities, which if taken advantage of, may in turn lead to develop mature and stable markets and systems surrounding the novel technologies. However, current and continued EV

[1] Soft infrastrucutre, as opposed to physical infrastructure, generally refers to sociatal knowledge and institutional aspects including laws, regulations, libraries, patent offices, research institutions and universities (Smith, 2009).

adoption is facing several challenges and barriers as complementary technology such as fast EV charging struggles within aspects such as commercial viability, legitimacy and mass adoption. Additionally, The Norwegian Government insists on a market driven approach of the potentially critical infrastructure, leading to several complex challenges for the novel technology and its market development.

Adoption, diffusion and utilization of technology within a system: Several of the challenges and barriers opposing further diffusion and utilization of EVs and charging technology arguably arises due to systemic failures or as a result of the emergence of a new technological paradigm within existing technological regimes, sectors, industries and underlying systems. Therefore, the issue of identifying, understanding and eventually reducing or removing barriers, as well as enforcing drivers, should be addressed by understanding incumbent regimes and the surrounding context in which the technology exists. Ideally combined with an understanding of the dynamics and functions of the encompassing technological innovation system (TIS), which is the main entity driving diffusion and utilization of the specific technology.

Understanding transitions and systems is a rather daunting task. A task undertaken by the recently developed and increasingly applied innovation system theory within the subject of transitions literature. A subsection of Innovation studies. The system analysis framework has become an increasingly popular and honed tool to both explain and support technological transition in modern economies and develop technology policy. Often applied by authorities and agencies such as The EU and The Organization for Economic Co-operation and Development (OECD). It also serves as an analytical framework for academic studies. Furthermore, this type of framework assumes that technology develops in a series of various interactions between several actors, networks and institutions within a conceptual system. As opposed to an often commonly perceived understanding of innovation being solely related to market aspects or research and development. Thus, in accordance with the context and challenges related to electrification of the Norwegian transportation sector via increased diffusion and utilization of fast EV charging technology, this study will examine this ongoing phenom through a qualitative system-lens.

1.2 Research questions

Based on the context of Norway's climate action and aspirations for an electrified transportation sector, the following research questions has been developed to attempt to increase understanding of how we can enable continued EV development via investigating and understanding drivers and barriers related to increased diffusion and utilization of complementary fast EV charging technology. Which in many ways can be understood as the most impactful measure for addressing the final hurdle of EV adoption in Norway.

- What are the functions and functionality of the Norwegian fast EV charging TIS?
- What is the role of the Norwegian government and how does it contribute to increase diffusion and utilization of fast EV charging technology in Norway today?
- What are the main overarching barriers and drivers for further diffusion and utilization of fast EV charging technology in Norway?

1.3 Scope and delineation

The process of delineating a TIS is complex and embodies several nuanced evaluations such as establishing conceptual limitations and borders of the focal TIS. Including, at least in this specific study, considerations towards a specific unit of analysis, technology, geographic limitation and value chain in addition to the surrounding and influencing context of the focal TIS. A more thorough delineation and definition of the focal TIS is therefore conducted in section 4.1 within the analysis chapter.

The scope of this study is concentrated on the specific technology and application context of fast EV charging technology within a system context in Norway. Encompassing how interplay through various actors contributes to diffuse and utilize fast EV chargers by making them available on public charging stations. Public charging stations containing charging points with an output capacity over 50 kW[2]. Other charging technology application contexts such as sea transportation charging, heavy vehicle charging or home- and destination charging is not excluded from this study but receives limited focus and are addressed within aspects where they serve to increase understanding of the focal TIS and its functions.

Furthermore, a limitation of the relevant aspects of the focal TIS within the geographical context of Norway seems reasonable since it contributes to simplify and limit the context of

[2] Also referred to as DC charging, as opposed to AC charging (normal charging) wich happens at 22 kW or lower

the system, while also reducing the size and complexity of the scope of this study. Additionally, since there has not been found any examples of technology generation or development related to fast EV charging in Norway, suppliers and aspects related to the global charging industry receives little attention. This is intentional since diffusion and utilization of fast EV charging technology is the main focus of this study. Furthermore, this focus is based on the assumption that fast EV charging technology currently can be considered established[3] enough to accommodate existing market needs within Norway. Consequently, this study is rather oriented towards market development via diffusion and utilization of technology, which can be considered *the production part*[4] of innovation within a TIS. As opposed to an industry-oriented focus where technology generation and development usually serves as the object of analysis and can be understood as *the innovation part* of innovation within a TIS.

Finally, a market-oriented scope supported by relevant and simplifying delineations contributes to hone the capabilities of this study by increasing its adherence to its goals and aspirations towards developing understanding of the system in which diffuses and utilizes fast EV charging technology in Norway. Furthermore, the scope and delineations of this study contributes to conceptualize barriers and drivers and enable increased understanding of how to further diffuse and utilize fast EV charging technology. Thereby attempting to support Norway's green transition within transportation by contributing to address the final hurdle of EV adoption.

1.4 Structure of the thesis

The following section will give the reader an introduction to relevant context and background related to the state of EVs and fast EV charging in Norway. Chapter 2 entails theoretical background and an elucidation of theoretical and analytical tools which later are combined into the *tailored analytical framework*, which is applied to analyze and discuss the focal TIS and the research questions. Chapter 3 encompasses methodical considerations such as data collection, research design, data analysis as well as a discussion related to reliability and

[3] Established in this context should not be compared with incumbent technologies, since neither EV- or EV charging technology should be considered incumbent. Established in this case refers to the maturity of the technology and its ability to address existing market needs at its current stage of development and availability.
[4] Markard and Truffer argues that innovation within systems can be divided into two separate areas of focus; *the innovation part*, with focus on generation, diffusion and use of new technologies and *the production part*, with focus on utilization and diffusion of established technologies (Markard & Truffer, 2008, p. 608). See section 2.2 for further elaboration and discussion.

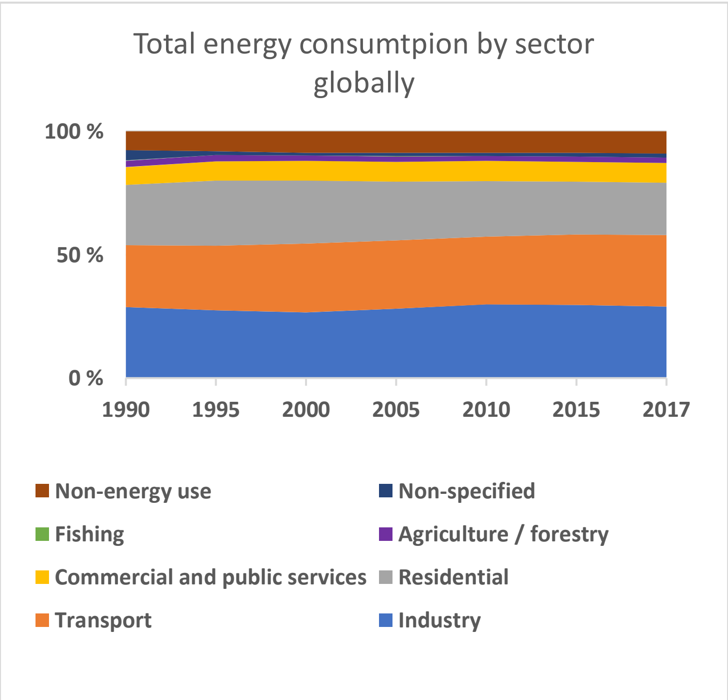
validity of this specific study. In chapter 4, an analysis of the focal TIS, its delineations and conceptual borders, functions and surrounding context is conducted. Followed by answering the research questions through a discussion of the functionality of the focal TIS, the role and contribution of The Norwegian Government and main drivers and barriers in chapter 5. Lastly, a few considerations towards limitation of research, suggestions for further research and policy recommendations are presented before a summary and concluding remarks are conducted chapter 6.

1.6 Empirical background and context

In this section, a more thorough introduction of energy, its role in society, decarbonization via electrification, and development of EV- and fast EV charging technology in Norway is conducted. Providing context as well as leading the topic of this thesis into the next chapter.

1.6.1 The notion of energy and the energy problem

To be able to understand the importance of energy, especially as part of large technological- and socioeconomic systems, it is valuable to understand what the phenom encompasses. Energy, as attempted defined by the physics discipline, entails the notion of energy as the ability to do work. Also defined as; "To exert a defined amount of force over a defined distance." (Haberl, 2015, p. 626). Throughout history, humans have depended on energy and its transformations for both survival and to enable our modern civilizations (Vaclav, 2017). There are defined several types of energy that occurs in socioeconomic systems; mechanical, chemical, heat, electric, radiant and nuclear. Energy exists in the world through energy flows (Haberl, 2015, p. 626). For example, the conversion of solar energy to plant mass through photosynthesis. Energy is linked to social constructs, such as human societies, through functioning, growth and sustenance by the means of energy flows and consumption of so-called free energies. Energy flows related to

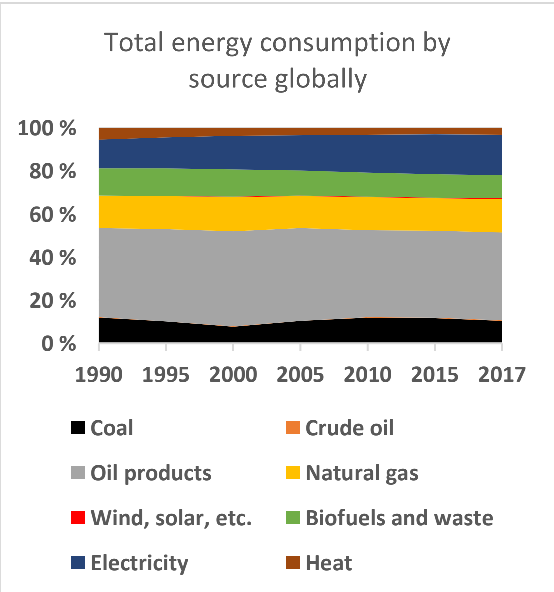


socioeconomic systems entail energy in forms such as food for humans and livestock, as well as the forms- and sources of energy we have chosen to fuel our artifacts (Vaclav, 2017).

Graph 1) ***Total energy consumption by sector globally*****. The graph describes relative consumption of energy across sectors. Furthermore, we can observe how the Industry, residential and transportation sectors represent about 60 % of global energy consumption from 1990 to 2017.** (IEA, 2019)**.**

The energy problem emerges as a consequence of human civilization's choice of- and dependency on conversion and consumption of fossil fuels for energy at massive scale, combined with an immense surge in demand due to population growth and increased living standards. Throughout history, we have created a society where we rely heavily on the conversion and consumption of fossil fuels to create free energies that we can consume to exert work in sectors such as transportation, industry and residential. Conversion and consumption which leads to one of several devastating consequences on our climate such as substantial amounts of greenhouse gasses (GHGs) being introduced to the atmosphere. This increased Introduction of GHGs have been proven to be one of the major drivers for current climate change. A fact well established and summarized by the United Nations (UN) through several scientific conclusions and arguments (UN, 2019).

The energy problem is compounded by several aspects. Population growth in addition to an increase in living standards through rapid eradication of poverty are both contributing to an upsurge in energy consumption. Annual global population growth has been hovering between 1,5 % - 2 % since the 1950s (Worldometers, 2019). This growth has left us with a population of 7.7 billion people at the time of writing (Worldometers, 2019). In terms of poverty, about 40 % of the world's population was living in extreme poverty in the 1980s. In the middle of the 2020s, only 10 % of the now substantially larger population is estimated to be living in poverty (Worldbank, 2019). With higher living standards comes higher energy consumption. Therefore, when considering energy consumption per capita, the future demand for energy can surely be expected to be immense.



Graph 2) ***Total energy consumption by source globally*****. The graph describes to which degree total energy consumption is met by the consumption of various energy sources. Furthermore, the graph shows the continued dependency and use of fossil fuels to meet global energy demand. A note should be made of the fact that the data for development ends at the year 2017, and that data and visualization of development throughout the years 2018 and 2019 surely should look somewhat more optimistic regarding use of RETs as energy sources if the data was available** (IEA, 2019)**.**

A substantial increase in energy demand from an existing energy system, which is still critically dependent on fossil fuels (Vaclav, 2017), represents a challenge since devastating climate effects are being recorded to an increasing degree every year. This speaks magnitude to the importance of looking for solutions and means to address the energy problem. A possible solution could be decarbonization via electrification of the modern economy. Possibly done in part through electrification of the transportation system which represents about 20 % of global energy consumption (IEA, 2019).

1.6.2 Decarbonization via electrification as a measure for climate change

Decarbonization can be summarized as a variety of policies and measures that aim to lessen the carbon footprint of the modern economy by reducing carbon in the energy equation. This roughly translates to reducing either the use of, or the consequences of the use of, fossil fuels in society. Methods of decarbonization can be divided into 3 main categories of approaches; 1) carbon reduction trough energy conservation or energy efficiency improvements, 2) carbon rejection through the means of for example carbon capture and storage (CCS) and 3) carbon abandonment by the use of other non-fossil fuel energy sources such as RETs, nuclear and hydro (Muradov, 2014, pp. 7-10). In short, decarbonization can in many ways be considered as one of the most significant answers to the energy problem. A point being underlined by Vaclav Smil in a statement made in 2015 where he urges continued effort and investment in decarbonization initiatives:

> Underlying all of the recent moves toward renewable energy is the conviction that such a transition should be accelerated in order to avoid some of the worst consequences of rapid anthropogenic global warming. (J.P Morgan, 2015, p. 2)

Electrification is one of several strategies for decarbonizing the global economy. What makes this strategy one of the more interesting and potentially high impact ones, is the fact that electrification can be applied to a large variety of aspects when it comes to consumption of energy in society in general. It is electricity's ability to be a versatile energy carrier that enables this form of energy to increasingly replace the use of carbon fuels in different parts of energy flow and consumption, while also being able to replace carbon produced energy-based artifacts at scale at a somewhat reasonable and increasing degree of convenience (Muradov, 2014, p. 314). A factor which is not a given for other strategies such as carbon rejection- or reduction. For example, non-carbon produced electricity can be applied to high GHG emitting and energy intense sectors such as residential, transportation and industry (ibid). Application by for example powering appliances, heating, vehicles or factories. Furthermore, electric energy can be acquired by alternative sources of non-carbon electricity production such as RETs, nuclear- and hydro (ibid) Which makes the measure even more advantageous in a decarbonization perspective.

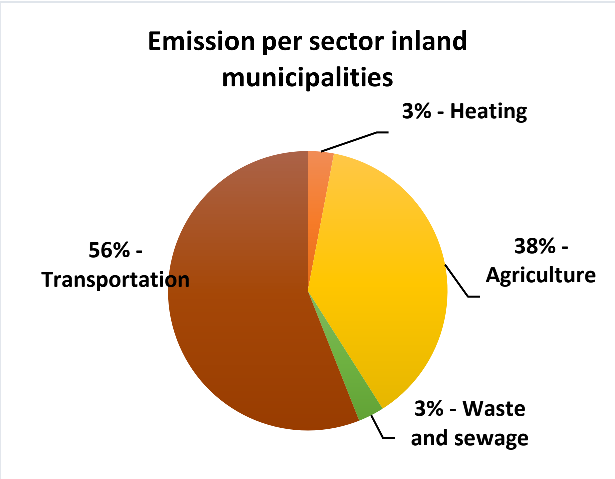
Several energy projections point to an intensified shift from high-carbon, to low-carbon, and eventually to zero-carbon electricity in the time-period leading up to 2050 (Muradov, 2014, p. 315). Furthermore, it has been found great potential in switching from direct consumption of fossil fuels in various artifacts, to consumption of electricity produced by means of fossil fuels, such as for example electric heating. A switch that could contribute to substantial reduction of carbon intensity in the economy. In California, it was found that increasing electricity as an end-consumption source of energy from 15 % to 55 %, in the time-period from 1990 to 2050, allegedly would lead to a reduction of GHG emissions by a staggering 80 % (Muradov, 2014, p. 315). The largest part of the emission reduction would come from electrification of the transportation sector. A sector which has a great potential in both electrification in addition to substantial GHG emission reduction.

The potential of electrification of the transportation sector emerges due to several factors. One factor is the share scale of number of artifacts and application contexts which can potentially be convert to electricity-based end-use energy consumption. Another highly relevant factor is the potential for emission reduction and decarbonization as a result of the fact that thermal/thermochemical processes are a lot less efficient compared to electric/electrochemical processes. Meaning the use of electricity in end-use requires less energy spent compared to end-use of fossil fuel sources of energy, e.g. use of an electric engine compared to a combustible engine leads to lower energy needs as well as potentially lower GHG emissions (Muradov, 2014, p. 315). The energy efficiency of electric engines is 3-4 times more efficient than combustible engines (ibid). This contributes to explain how future projections for the transportation sector in countries like Norway shows a declining energy demand, despite a continued growth in traffic (Fridstrøm & TØI, 2019, p. 9).

1.6.3 Decarbonization via electrification in Norway

Norway has set clear and ambitious goals for a low emission transportation sector along with a vision of becoming a low emission society by 2050. This ambition is clearly demonstrated by the Norwegian government in the National Transportation Plan 2018-2029[5], where visions, goals and commitments are explicitly stated. The Norwegian government strongly and publicly commits to climate related obligations by adhering to actors and collaborations such as the EU and The Paris-agreement related to the UN. Among other goals, the Norwegian government states that all new passenger vehicles and light vans shall be ZEVs by 2025 (2017, p. 217). Furthermore, all new city buses shall be either 0-emission or running on biofuel (ibid). In terms of heavy vans, trucks and long-distance buses, the Norwegian government states that by 2030, all new heavy vans, 75 % of all new long-distance buses and 50 % of all new trucks shall be 0-emission vehicles (ibid). In terms of boats and sea transportation, it is stated that 40 % of short sea ships shall be zero emission by 2030. Additionally, all ferry activity related to public transportation within municipalities shall receive support to enable zero emission ferries. The municipalities shall also receive general support in regard to enable climate friendly public transportation (ibid).

Furthermore, the transportation sector stands out as a natural choice when it comes to finding an appropriate candidate to focus electrification initiatives on to be able to meet international climate commitments. This is in part due to the fact that Norway's access to locally produced, cheap and renewable hydro energy enables the residential- and industry sectors to consume already low GHG emission energy based on electricity. Which leaves these sectors with a relatively small carbon footprint compared to the transportation sector. Due to the degree of ICEVs in the Norwegian carpark, much of the transportation is based on fossil fuel consuming technology. Leaving decent margins on potential for electrification. For example, the inland municipalities within the County Municipality of Agder found that 56 % of their 2018 emissions could be reduced by realizing the potential of overall electrification by moving from a degree of 61 % electrification to 95 % (County Municipality of Agder, 2018).



[5] The NTP, Norway's periodcally governing transportation policy document. Norwegian transportation is currently subject to the policy agenda of NTP 2018-2029 since its implementation in 2017. The next NTP will be implemented by 2021 (The Norwegian Government, 2020).

Graph 3) *Emission per sector inland municipalities*. The graph displays GHG emissions divided per sector in regards to inland municipalites within the County Municipality of Agder. As per the graph, we can observe how transportation represents 56 % of emissions within the county municipality (County Municipality of Agder, 2018)**.**

The County Municipality of Agder's reductions in GHG emission would largely be due to electrification of the transportation sector, since addressing the Norwegian agricultural sector often can be politically risky and complicated. In terms of degree of electrification, only 1 % of road transportation in The County Municipality of Agder could be considered electrified in 2018, while 13 % was operating on biofuel and other non-electricity based RETs. Leaving 87 % of transportation within the inland municipalities running on fossil fuels (ibid). Overall, the County Municipality of Agder reports an average electrification degree of 61 %, where energy supply, including district heating, already enjoys a degree of 92 % electrification and industry experiences 100 % (ibid). It should be noted that the County Municipality of Agder is unique when it comes to aspects such as access to clean and locally produced energy, traffic pattern and industry. For example, they have no ferries. Therefore, the premise of the County Municipality of Agder is not necessarily equal or completely representative for all other municipalities throughout Norway. However, the case of Agder is a good example of how transportation is seemingly the most natural option for electrification based on, among other factors, margins for electrification and potential outcome.

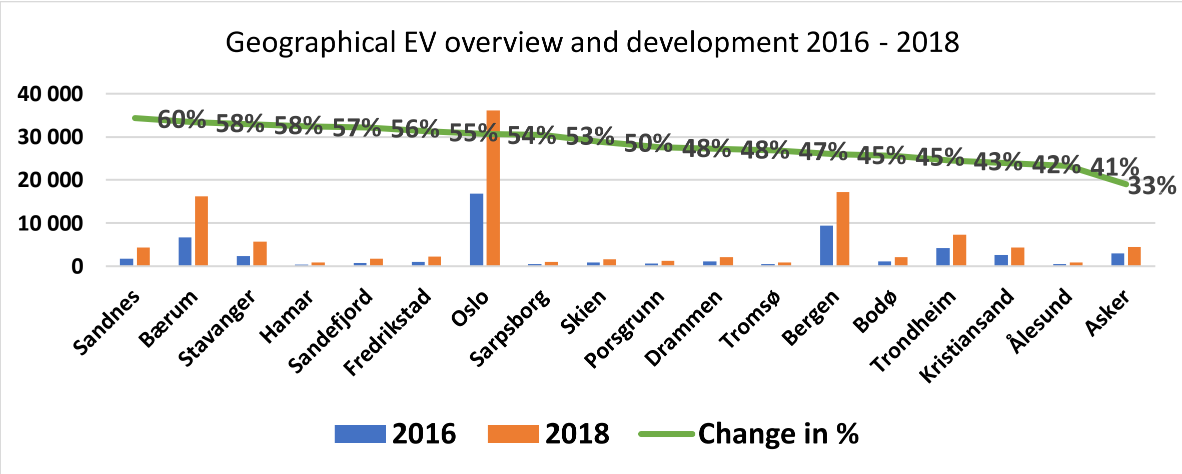
1.6.4 EV development in Norway

The Norwegian car park is remarkable due to its relative share of battery electric vehicles[6] (BEVs) and plug-in hybrid electric vehicles (PHEVs) , making Norway a pioneer and frontrunner in terms of adoption of low emission vehicles, relatively speaking (IEA, 2019). In 2017, 5,1 % of the Norwegian car park consisted of BEVs, and an additional 2,6 % was made up of PHEVs (Figenbaum & TØI, 2018), making Norway one of 5 countries with a considerable share of electric vehicles as part of their car park (IEA, 2019). Furthermore, a remarkable 44 % of the 2019 Norwegian new passenger car sales consisted of BEVs and PHEVs (The Norwegian EV Association, 2019). An astonishing feat considering the next two countries in line, when it comes to low emission vehicle market share of new car sales is only about 17 % in Iceland and 8 % in Sweden (IEA, 2019). China represents the biggest market of BEVS and PHEVs with 2,3 million, followed by 1,2 million in Europe, 1,1 million in USA

[6] Due to various terms in relation to application contexts of for example electric vehicles and other low emission vehicles, a clarification is in order. EVs refers to all BEVs and PHEVs. Zero emission vehicles (ZEVs) refers to all low emission vehicles including hydro and biogas. Although, not all forms of for example hybrid contexts since these are arguably not zero emission vehicles to the same extent.

(ibid) and about 300.000 in Norway by the end of 2019 (The Norwegian EV Association, 2019).

Looking at geographical distribution and development of EVs across occurring cities in Norway between 2016 and 2018, we see that major cities and urban areas typically stand out in terms of occurring and increasing numbers of EVs. Geographical distribution of EVs is important when it comes to understanding and accommodating the need for complementary infrastructure. This is because the occurrence and use of EVs drives the traffic pattern[7]. Furthermore, number and use of EVs is the main explanatory factor for the use of fast EV charging stations, which in turn drives their profitability and commercial viability.



Graph 5) *Geographical EV overview and development*. The graph describes the geographical distribution and development in numbers of EVs across the largest and most relevant Norwegian cities in terms of EV occurrence from 2016 - 2018. The green line describes relative increase of EVs from 2016 - 2018, with a total number of 195.451 EVs in 2018 (SSB, 2019)**.**

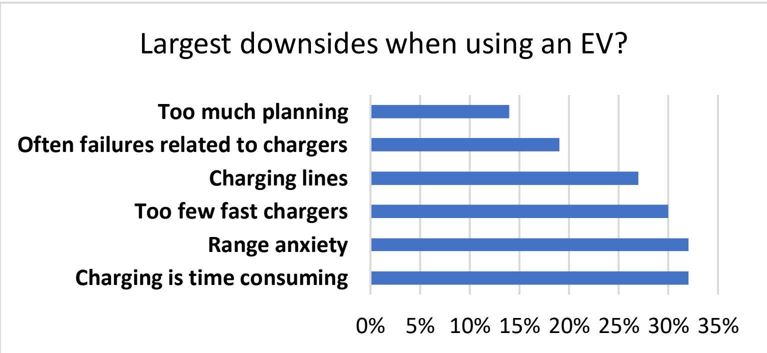
The future development of the Norwegian car park has been analyzed and projected in connection with the development of the next NTP 2022-2033. In short, the number of Norwegian passenger cars are expected to increase by 13 %, and heavy duty vehicles are expected to grow by 25 % by 2030 (Fridstrøm & TØI, 2019). Furthermore, a best-case scenario suggests that up to 62 % of the passenger car park could be ZEVs by 2030 (ibid). Additionally, massive adoption is projected for BEVs, involving from 70 % up to 99 % of all new passenger vehicles to be BEVs by 2030 (ibid). Outlook for heavy duty ZEVs, including biogas, is also projected to be staggeringly high with projections and optimistic scenarios reaching up to 63 % market penetration for new buses and coaches by 2030 (ibid). To optimistically summarize the projected future of the Norwegian passenger car park, we could

[7] Own translation of "trafikkbilde", referring to the amount of use of for example EVs within a given area.

possibly see 77 % of all new passenger vehicles be ZEVs by 2021 and the total stock of the Norwegian passenger car park to be 77 % ZEVs within 2033 (ibid).

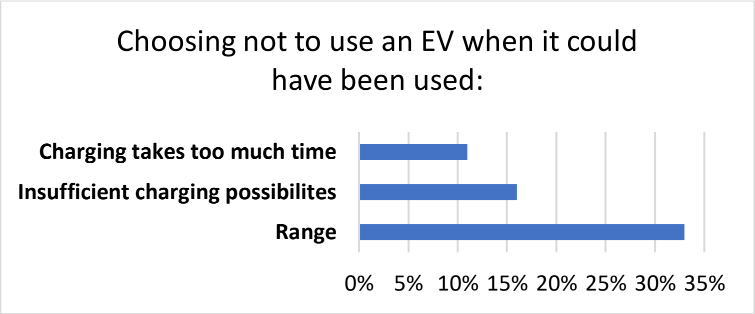
1.6.5 Fast EV charging stations as a measure for further electrification

As we have established, the use of EVs by means of locally produced green electricity from the Norwegian power grid, allows for a substantial reduction in GHG output as well as an overall decrease in energy needs related to transportation in Norway (The ministry of transport, 2019). Which is great news for both Norway and the climate, since the Norwegian transportation sector accounts for about 30 % of Norway's emissions (ibid). However, a lack of suitable and adequate charging infrastructure appears to be an issue in the Norwegian marketplace. This becomes apparent when comparing current development of existing chargeable vehicles, to the development of publicly available fast charging infrastructure capabilities. According to Nobil, there are presently 1.442 fast and semi-fast charging stations with charging points with an effect over 20 kW or more in Norway in early 2020 (Nobil, 2020). Furthermore, The Norwegian EV association states that 2.700 charging points now are available throughout Norway (The Norwegian EV association, 2020). However, the 1.442 fast and semi-fast charging stations are currently serving approximately a staggering 300.000 EVs (The Norwegian EV Association, 2020). That's roughly 300 vehicles per charging station[8] with 1 or more charging points capable of delivering 20 kW or more[9]. By observing the findings of the Norwegian EV Association's annual EV user survey from 2019, we find the following regarding experienced access and use of fast charging infrastructure and EVs in Norway;



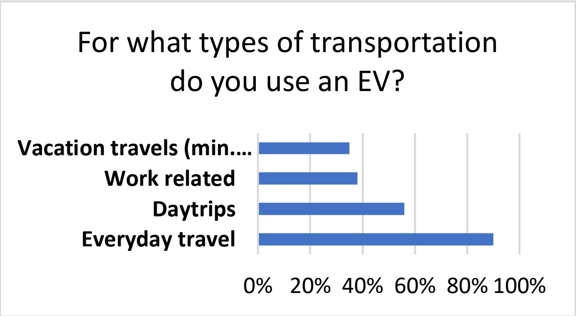
Graph 6) ***Downsides of using an EV*****. When asked about the downsides of using an EV, the above reasons were stated by EV users** (The Norwegian EV Association (a), 2019)**. As we can see, most of the stated reasons relates directly, or indirectly, to access to- and use of fast charging infrastructure.**

[8] A charging station contains one or several charging points. A charging point can serve one EV at one time, however a charging station may serve several EVs at one time.
[9] Consistent with an estimated charging time of 1 hour or less (Ladestasjoner.no, 2020)



Graph 7) ***Choosing not to use an EV when it could have been used.*** **The graph describes the most occurring scenarios where respondents choose not to use their EV, where the EV theoretically could have been used** (The Norwegian EV Association (a), 2019)**. It is important to note that these are not all the stated reasons. However, they are the most occurring and relevant ones. Again, we can observe that access and use of fast EV charging infrastructure is a significant barrier for further EV usage and adoption.**

Additionally, 44 % of respondents stated that they were planning to use their EVs during the summer vacation. On the other hand, this means that about 56 % of EV owners were probably not planning to use an EV, since many of the households who owns an EV also owns an ICEV (The Norwegian EV Association (a), 2019). Meaning that the preferred vehicle for long time and distance travel in many cases is an ICEV.



Graph 8) ***Types of travels where an EV is being used.*** **In this graph, we can observe how the EV is used for short travels or errands such as getting to and from work, shopping and training etc... However, usage falls off as soon as the range and time dimension of the travel increases** (The Norwegian EV Association (a), 2019)**.**

Based on these facts and observations, access to fast EV charging capabilities is seemingly a final hurdle for mass adoption and widespread usage of EVs in Norway today. The Norwegian Government somewhat agrees, as it has ostensibly expressed its understanding and realization of the need for increased access and availability of fast EV charging infrastructure. In 2019, The Norwegian Government made the following statement in the government's *action plan for infrastructure related to alternative fuels in transportation*[10];

> The government will accommodate for fast expansion of charging infrastructure throughout the country through a combination of public- and marked based solutions to keep up with the increase of electric vehicles (The ministry of transport, 2019, p. 5).

On the other hand, The Norwegian Government has expressed its inclination towards a commercially driven market approach. An approach where private actors take responsibility

[10] Own translation of the name of the report; The Norwegian Government's action plan: "Handlingsplan for infrastruktur for alternative drivstoff i transport".

for developing fast EV charging infrastructure based on its commercial viability and profitability (Enova (b), 2019). Furthermore, the stated ambitions and goalsetting of The Norwegian Government has been criticized as vague and unspecific due to lack of for example explicit goals, including their latest action plan (NAF, 2019). Additionally, there barely exists any mentions of charging infrastructure in current NTP (The Norwegian Goverment, 2017). Mentions that does exists are most often related to Enova driven initiatives for financial support (ibid).

Taking a position of a privately market-driven development of infrastructure, infrastructure which in many ways could be considered critical in the near future, could arguably be less fortunate then a more state-driven approach. This position may also have led to a vacuum in terms of an overarching plan. Including division of responsibilities and addressing for example negatively influencing and impending aspects[11] and overarching barriers[12] as a result of the emergence of this new technological innovation system within the context of incumbent regimes, sectors, industries and markets.

Other critical factors such as the technical aspect of potential charging capacity, digital and smart IT-solutions as well as power grid infrastructure and energy production-readiness are evidently sufficient to serve an electrified Norwegian car park (The ministry of transport, 2019). Modern and commercially available charging technology has a potential capacity of delivering up to 450 kW, which if applied would be able to substantially reduce time spent charging an EV (Ladestasjoner.no, 2020). Such levels of output capacity are already potentially available at some fast EV charging stations today. However, modern EVs and their batteries are not yet able to take complete advantage of such high levels of output. When it comes to readiness of the Norwegian power grid and energy supply, current and available infrastructure and energy production should be able to meet increased energy demands from the transportation sector (The ministry of transport, 2019). The commercial readiness in terms of increased effect loads and outputs on the power grid on the other hand, is seemingly less ready (ibid). Furthermore, the use of digital solutions such as AMS-meters and smart energy services should contribute to reduce peak loads on grid infrastructure. However, fast EV

[11] Negatively influencing and impending aspects are mechanisms that contributes to reduce or hamper the fulfillment of one or several functions and the overall functionality of the focal TIS. As opposed to positively influencing and supporting aspects.

[12] Overarching barriers are in many ways similar to negatively influencing and impending aspects. However, this concept refers to barriers in which is conceptually based in the surrounding context of the focal TIS as well as its internal functions and functionally. Overarching barriers are opposed by overarching drivers.

charging stations may increase local needs for energy output, both seasonally and regularly (The ministry of transport, 2019).

To summarize, it seems like the Norwegian EV charging market to some extent has failed to meet the growing demand for fast EV charging infrastructure and that this market failure will potentially lead to reduced adoption and usage of EVs with possibility of stagnation if not addressed. Furthermore, since current underlying infrastructure appears ready and physically available, together with practically few technical challenges related to IT-solutions as well as the technical aspect of charging EVs, this leaves the question of what the current barriers are for further development of the Norwegian fast EV charging infrastructure. How can these barriers be identified and eventually reduced, or even be completely removed? Furthermore, what are the drivers for current and future development of EVs and Norwegian fast EV charging infrastructure? Can these drivers be reinforced for increased development? If so, how can they be enforced? Such questions are a suitable challenge for an innovation-based framework. Since innovation, EVs and fast EV charging are all arguably of a systemic nature as well as being highly complex. Moreover, building a system-oriented analytical framework which focuses on the *production part* of innovation, with technology as a departure for analysis, seems apt within this context. As opposed to an arguably narrower and less adapted rationale of the market failure-approach (Bleda & Río, 2013). Finally, the technological development and generation of EVs and EV charging technologies seems mature enough for mass adoption and widespread use as per initially established and commercially available technology.

2. THEORETICAL BACKGROUND AND FRAMEWORK

In this chapter, I will imbed the case of electrification of the Norwegian transportation sector and the focal TIS within the context of innovation by introducing relevant theoretical background related to the analytical framework applied to this study. Furthermore, I will expound upon analytical tools and frameworks which will be applied to answer the research questions. Lastly, a presentation of what will be referred to as *the tailored analytical framework* as well a discussion regarding its concepts and application will be conducted at the end of this chapter.

2.1 Innovation studies

This study takes place within the discipline of innovation studies. More specifically, transition studies containing system theory. Innovation, a phenom as old as humanity itself spans concepts such as for example innovation systems, measuring innovation, effects of innovation and innovation policy (Fagerberg, Mowery, & Nelson, 2004). However, attention and application of the subject of innovation has become increasingly pertinent in recent times as opposed to past decades. When innovation studies emerged as a separate field during the 1960s, it did so under terms considered less prestigious at the time. Within disciplines such as policy- or science studies (Fagerberg, 2004). In modern times, innovation studies have become increasingly multidisciplinary and relevant through an increased understanding of the phenom in social and economic contexts. Furthermore, as stated by Fagerberg; "Innovation is by its very nature a systemic phenomenon" (2004, p. 3). An aspect that makes the concept of innovation arguably more apt than other scholarly disciplines to define, frame and analyze complex social and economic systems of innovation.

When it comes to the phenom of innovation, a distinction between innovation and invention is made. *Invention* is related to the first occurrence of an idea for a new product or process. *Innovation* is related to the first commercialization of such ideas. The concepts can often become closely linked and challenging to separate. However, time lag between invention and innovation often occurs (Fagerberg, Mowery, & Nelson, 2004). For example, the invention of the electric vehicle occurred as early as the late 1800s, yet the innovation of EVs arguably did not taken place before sometime in 2010 in for example Norway. At least not at a significant scale.

To be able to turn an invention into an innovation, an act mostly, yet not exclusively, occurring in firms, different types of resources, knowledge, capabilities and skills is applied by an innovator (entrepreneur). The process of both invention and innovation is considered continuous due to the fact that improvements and changes occur continually to an artifact as it is exposed to even more inventions and innovation over time (ibid). Again, the case of the car or even the electric car is a good example of incremental continuous change over time. From the first prototypes made in the 1800s to the modern vehicles driven today.

To summarize and define, innovation as a concept is complex due to its multidisciplinary traits combined with the amount of social, economic and technological components, connections and effects it is attempting to comprehend. Analyzing a system such as the Norwegian fast EV charging TIS is a multiplex challenge in itself. A challenge where a term like innovation and an analytical concept such as system analysis arguably is the best tool to apply since a system is the target of analysis. Defining innovation in line with the aspirations, scope and applied concepts of this study is another challenge since, definitions and applications of the phenom are as abundant as they are varying. However, I have come to choose the following definition due to its broad and inclusive, yet highly descriptive definition of innovation. The definition arguably covers many, or even all of the concepts, views and considerations I am undertaking within this study;

> Innovation is: production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems. It is both a process and an outcome (Crossan & Apaydin, 2010, p. 2).

One of the reasons as to why this definition can be viewed as highly appropriate for this study, is the fact that Crossan and Apaydin undertakes a broad research of much of existing innovation literature. Furthermore, the above definition summarizes their view and understanding of the concept. This definition is also in line with elementary understanding of terms such as systems of innovation (Edquist, 2005). Additionally, the above definition embodies several aspects of system innovation in regard to different components, their relationships, goals and functions. A trait that complements the view of the concept of innovation in regard to an analytical tool such as a transition- and system-oriented framework. Furthermore, the definition aptly illustrates how both the EV- and complementary fast EV charging technology can be considered innovation, or innovative, due to these technologies value-adding novelties. Novelties such as a reduction of energy consumption, reduction of GHG emissions and emergence of new charging infrastructure to enable increased adoption and diffusion of EVs. These technologies are also highly digital, bringing on novel opportunities and challenges.

2.2 Systems within innovation

The systems literature has emerged as a result of the need and want to conduct empirical studies of innovation systems. The need and the want sprung from an aspiration to understand these system's structure, function and dynamics. Often to provide policy developers and governing institutions with actionable insights (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008). When discussing system analysis, it is important to establish an understanding of what the concept of a system entails. Bergek defines the term *system* as follows; "A group of components (devices, objects or agents) serving a common purpose, I.e. working towards a common objective or overall function." (2008, p. 2). Furthermore, the TIS-notion is often applied as a governing analytical concept to describe a socio-technological system in which the focus is concentrated towards development, diffusion and utilization of a specific technology. Often in form of for example knowledge or a product. The TIS-notion is therefore highly applicable when aspiring to analyze a system such as a charging infrastructure network. The following definition of a TIS will serve as the governing context when referering to the term;

> A technological innovation system is a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product (Markard & Truffer, 2008, p. 611).

The definition focuses on the innovation function of the system, applies a technology specific perspective while also limiting the system to supportive actors, institutions and networks (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008) (Markard & Truffer, 2008).

When considering the application of system theory in general, a distinction can be made in regard to analytical system-tools such as the TIS- and the MLP-approaches when it comes to the role of innovation. Markard and Truffer argues that innovation within systems can be divided into two separate areas of focus; *the innovation part*, with focus on generation, diffusion and use of new technologies and *the production part*, with focus on utilization and diffusion of established technologies (Markard & Truffer, 2008, p. 608) This study will concentrate on the latter of the 2 roles of innovation within systems. This is due to the nature of the Norwegian fast EV charging TIS as well as how fast EV charging technology in several aspects can be considered to be an established technology. Although not at all an incumbent technology. This study's preference towards *the production part* of innovation is based on the fact that seemingly little to no technology generation and development takes place within Norway. Furthermore, aspects such as diffusion, utilization and commercialization within the context of the focal TIS is arguably of a higher interest and relevance when addressing the research questions and aspirations of this study. Additionally, potential and available charging technology currently greatly outperforms existing market needs and capabilities in terms of charging capacity within EVs in the Norwegian market. Finally, most of the CPOs in Norway are third party charging point operators (3CPOs), whom procures and consumes technology from suppliers and technology developers located outside of Norway. Therefore, Increased diffusion and utilization, or what can be considered to be *the production part* of innovation, is to a large degree describing the process which is taking place within the Norwegian EV- and EV charging TISs. As opposed to *the innovation part*.

2.3 The concept and role of infrastructure

Developing underlying and complementary infrastructure related to new and emerging technologies is essential in order to increase further diffusion and adoption of such novelties. Diffusion and adoption of EVs and fast EV charging infrastructure is no exception. Therefore, it is relevant to discuss the term *infrastructure* in depth since it entails several meanings throughout applied literature, business, every-day life as well as application within this study.

Freeman argues that radical technologies which drives regime change requires an intrinsic infrastructure in order to establish itself as the new regime (2001). Vaclav supports this view by underlining the importance of both new and existing infrastructure in past, future and current energy transitions (2017). Furthermore, Smith agrees. He argues that goal-oriented changes must be made in infrastructure, systems of knowledge and use-patterns that embodies regimes in order to induce regime-change. Smith further contends that in order to facilitate radical innovation[13] such as regime-change, governments needs to support the technology directly, develop accompanying infrastructure or even apply both strategies (2009). He summarizes infrastructure into 2 categories; *Physical infrastructure*, such as for example the power grid, roads and seaports and *knowledge infrastructure*, such as libraries, patent offices,

[13] Smith refers to and defines *radical innovation* as follows: "Technological regime shifts, involving wholly new technical functions, new knowledge bases, and new organisational forms, such as the transition from steam power systems to electricity." (Smith, 2009, p. 3)

research institutions and universities (2009, p. 22). Often referred to as *soft infrastructure*. According to Smith, Infrastructure is particularly capital intensive, has long investment horizons, long lifetime cycles and possesses the ability to both shape and constraint system innovation (ibid)

An overarching definition of the term *infrastructure* has seemingly not yet been thoroughly agreed upon. This can be observed in Smith's study and discussion of the term in a system perspective (1997). According to Andersen, in relation to the term in innovation studies, Infrastructure often refers to; *"*A static structural constraint that gives direction to innovation activities" (2014, p. 78). Due to the wide application and meaning of the term, and to simplify, I will apply the following definition developed by Smith when referring to the term *Infrastructure* throughout this study: "The complex of non-natural resources that are collectively used by industry in the production and distribution of products.*"* (1997, p. 90). Even though the above definition of the infrastructure term is somewhat broad, the definition is arguably suitable when considering the context of having charging infrastructure as the object of analysis. The above definition is apt since it encompasses both EV charging infrastructure as well as the more traditionally accepted types of infrastructure such as for example the power grid, sewage and roads. More specific definitions of the term exist. However, as a consequence of the short life span of the term within for example economics, few of these definitions aptly describes infrastructure in a suitable way for a TIS-analysis. This is often due to the fact that economic definitions tend to help shape the term into more quantifiable and measurable terms (Smith, 1997) and not necessarily to be applied to a qualitative and system-oriented case study.

Since Infrastructure is considered a rather loosely defined term in regard to innovation studies and in general, the term has yet to be highly conceptualized to a large extent (Andersen, 2014). Although the relevance of infrastructure has been thoroughly established in several aspects, including the system- and transitions literature. Andersen refers to and conceptualizes the term in a sectoral aspect as follows:

> We understand an infrastructure sector as a socio-technical system of fundamental importance to the functioning of society in areas such as water, energy, internet, and transport. It consists of physical components, technologies, actors, and institutions. Its particular properties imply that infrastructure transformation is immensely challenging (2014, p. 77).

Andersen's notion of an infrastructure sector provides a suitable consideration towards the importance and influence of infrastructure as a physical artifact, its interplay with soft infrastructure as well as putting the term into the context of society in general. In addition to the context, Andersen argues that infrastructure should be analyzed through a dynamic methodology. Mainly a system-oriented approach (ibid). By applying a system approach, such as the TIS- and MLP-frameworks, both the social and the technological aspects of infrastructure can be examined and understood. The analyst should therefore be more able to consider all relevant actors, institutions and technical components. Rather than having the analyst apply less dynamic approaches such as for example an engineering approach with focus on technical efficiency, or a regulatory perspective with focus on economic performance (Andersen, 2014, p. 78).

2.4 The functions and functionality of a technological innovation system

As mentioned in the previous chapter, a system-oriented framework is suitable when aspiring to describe and understand an infrastructure-technology focused TIS by defining and analyzing its functions, functionality and surrounding context. *The scheme of analysis* has been a popular framework applied to examine and understand systems within a transition context, as well as improving basis for decision in regard to governmental policy interventions related to complex systems. As opposed to top-down interventions related to the considerably less complex and system-oriented neoclassical economics-rationale behind market failure[14] (Bleda & Río, 2013). Based on these considerations, describing and understanding the development of the Norwegian fast EV charging TIS, in addition to attempt to provide proficient guidelines for Norwegian innovation policy intervention in order to facilitate further diffusion and utilization of fast EV charging technology, these factors seems best served by applying a systemic rationale and framework. Therefore, the following scheme of analysis will be serving as the governing framework within this study.

The scheme of analysis approach is focused on both structural influence on innovation as well as its processes. As opposed to system failures in a system's structure, which has often been the case for much of the previous TIS literature. (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). In terms of the TIS-framework, Bergek has outlined a 6-step process of

[14] The market failure-approach consideres the neoclassical economical understanding that market failure entails a situation where allocated goods and services distributed by a free market is not pareto efficient. This lack of pareto efficieny can lead to a net loss of economic value (Bleda & Río, 2013).

analysis. Including 7 key processes to describe and frame a TIS within her take of an operationalized and refined TIS-framework, *the scheme of analysis*. The processes within a TIS are referred to as functions. The functions have a clear impact on development, diffusion and utilization of technologies from a systemic perspective, with focus on the dynamics of that system which leads to what is to be achieved. In this case, mainly diffusion and utilization of an initially established technology.

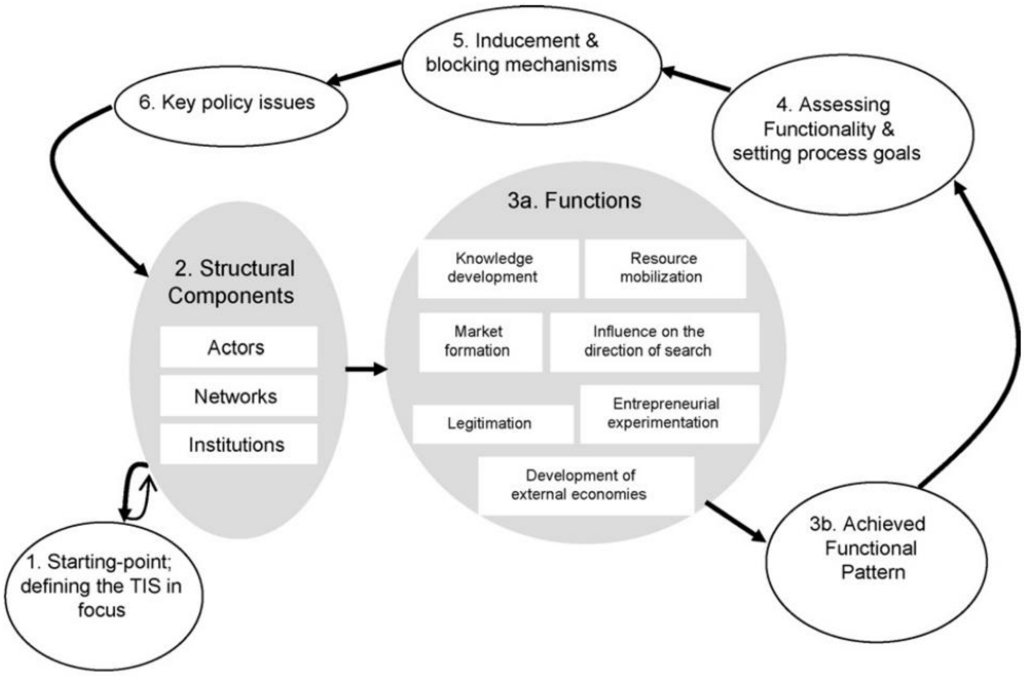


Figure 1) *The scheme of analysis*. The Figure describes the 6 steps of the scheme of analysis-approach (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, p. 413)**.**

2.4.1 Defining the TIS

The process of defining a TIS can be outlined by first and foremost formulating an explicit unit of analysis, to then consider 3 governing aspects. The first aspect covers the choice between either a knowledge field or a product as the analytical object. The second aspect revolves around the choice regarding the breadth or depth of the analysis. Lastly, the third aspect considers spatial domain (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, p. 413). TISs are generally global in character. Various reasons and arguments may however lead to beneficial limitation of the TISs to enable focus on specific aspects such as a national or regional context. Furthermore, defining the TIS should be considered a learning process which needs to adapt along the way as information and understanding increases. Therefore, it is often beneficial to have a broad starting point, to then narrow down the study (ibid). The same is true for the focus and scope of the study. Especially considering an emerging TIS due to its ability to develop and change in directions and ways that is unexpected and potentially radical.

Bergek also argues that a geographical delimitation of a global TIS should not be used by itself and that an analysis should attempt to consider international components related to the TIS. This comes as a consequence of the fact that a spatially limited part of a global TIS can be hard to understand and asses without a considerable understanding of the global attributes of the TIS (ibid). Lastly, Sanden expands upon the method of delimiting and defining TISs beyond a geographical limitation. He recommends the following: “We suggest that system boundaries for TISs need to be made in at least four dimensions: technology, value chain, time and geography.” (2008, p. 3).

2.4.2 Identifying the structural components of the TIS.

First components of a TIS to be identified are the actors. These may include various firms within the value chain, educational- and research institutions, VCs, associations and other interest groups, public bodies and other entities whom can for example establish industry standards or contribute to other relevant factors within soft infrastructure related to the TIS (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, p. 413). The second part of identifying the structural parts of a TIS is mapping networks. Networks can be both formal and informal. Examples of formal networks are amongst other; consortia, associations, customer representations groups, public-private partnerships, supplier- and or acquisition groups. More informal networks can be for example; university and industry collaborations, social communities or customer interest groups (ibid). Third and lastly, mapping relevant institutions. Institutions entails organizations and agents that control, influence or otherwise affect culture, norms, regulations and laws relevant for the TIS (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, p. 414). Institutions can both be a driving- and impending factor when it comes to the development of a TIS. Existing institutions can be blocking the development of a TIS through lack of alignment or adaptation to the new emerging system. Additionally, firms may compete over the governing institutional set-up as well as general competition within the market. On the other hand, a lack of institutions can also lead to induce barriers and negatively influencing impending aspects for the TIS by for example not securing a free market or adapting existing laws or policies. For an emerging TIS, institutions may be lacking or may not be existing at all (ibid).

2.4.3 Mapping the functional pattern of the TIS.

This part of the scheme of analysis undertakes the goal of describing the functional patterns of the TIS. Meaning increase understanding regarding the extent to which various functions in the TIS are fulfilled, and to what degree. In short, the analysis attempts to explain how the TIS is functioning considering 7 key processes which will be described below (ibid).

Knowledge development and diffusion: This function considers current attributes of the TISs knowledge base, how it changes over time and how that knowledge is diffused and used within the system. Knowledge can be placed into different categories; product, technological, market, logistics, design, and scientific knowledge. Furthermore, Bergek distinguishes between different types of sources of knowledge development. Amongst other sources; Imitation, R&D and learning from new applications (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, pp. 414-415).

Influence on the direction of search: Growth and development of a TIS is largely driven by organizations and firms entering the new system. For such entities to desire to become a part of a new TIS, incentives and various forms of pressure needs to be present combined with mechanisms referred to as; “The direction of search within the TIS” (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, p. 415). These factors can be measured, or at least indicated, through for example qualitative attributes such as; beliefs in growth potential, incentives from suppliers and producers, regulatory pressures and expressed interest from significant customers (ibid).

Entrepreneurial experimentation: A TIS develops under naturally high uncertainty when it comes to technologies, applications and markets. An answer to this uncertainty is, at least from a social perspective, entrepreneurial experimentation which may lead to social learning processes (ibid). A TIS without such experimentation will certainly stagnate. To measure or gage the degree of entrepreneurial experimentation of a TIS, an analyst can investigate the number of relevant experiments in relation to the TIS in question. Examples of units of measurement could be; New entrants and diversifying established firms, number of various types of relevant applications and breadth of technologies applied together with the attributes of complementary technologies applied in the TIS (ibid).

Market formation: In an emerging TIS, markets may be underdeveloped or even non-existent. This may include for example immature potential customers with little or no means to express their interest and demands. Moreover, price relative to performance for the technology may be subpar compared to competing solutions and technologies in addition to a wide array of uncertainty related to lack of industry standards or presence as well as influence of institutions (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, p. 416). There are 3 stages of market formation, nursing, bridging and mature (mass). initially a limited and small market in the form of a nursing market needs to be established to enable a new TIS to emerge by means of learning spaces. This nursing market can eventually give way to a bridging market. A bridging market is often characterized by larger volumes and an increase in number of actors in the emerging TIS. Finally, pending the success of a TIS, a mass market may form in terms of scale and volume. The market formation from nursing- to mass market often takes time. In some cases, even up to several decades (ibid).

To measure and analyze market formation, the analyst needs to comprehend both what drives the market together with actual market development. Actual market development is less challenging to describe as market sizes are often already measured to some degree (ibid). For instance, the number of EVs as well as EV charging stations in Norway could be used to describe market size and development. Analyzing what drives a TIS is rather more complex. In short, an analyst needs to categorize the current market and TIS in the correct stage of development and then move on to identifying the users and their purchasing processes. Furthermore, the analyst needs to map the articulation of demand profile together with finding out who is articulating the demand. Lastly, the analyst needs to understand the state of institutional stimuli. Stimuli in terms of either stimuli for market formation or lack of stimuli, which leads to for example a need for institutional change (ibid).

Legitimation: Legitimation is necessary for a TIS to form. Legitimation encompasses both institutional compliance as well as social acceptance. Meaning that the technology in questions needs to meet a need or a value proposition expressed by relevant actors to enable resource mobilization. Resource mobilization leads to empowerment of actors within the TIS, which again leads to political strength. Furthermore, legitimation is considered a dynamic process necessary to overcome a TISs so called *liability of newness* (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, pp. 416-417). This process is often challenged by for example competing, emerging and incumbent TISs together with existing policies and the institutional network surrounding and influencing them. There are several strategies for legitimation. Some of them are; manipulation of the rules through institutional alignment, conformance by adhering to existing rules, frameworks or standards and lastly creation, whereby a new framework, standard or rules are being developed specifically in relation to the emerging TIS (ibid). For an analyst to measure, map and analyze the function of legitimation, understanding both legitimacy of the TIS given by relevant actors and stakeholders as well as activities within the TIS that may improve legitimacy, is necessary. Such an analysis can be done through 3 central factors; 1) The strength of legitimacy, in terms of degree of alignment between a TIS and relevant legislation, together with value base in society and industry. 2) How legitimacy influences legislation, firm behavior and demand. 3) What and who, that effects and influences legitimacy combined with how this influence and effect is practiced (ibid).

Resource mobilization: Through further development of a TIS, an increased need for resource mobilization arises. Resource mobilization is related to a TIS's capability to recruit resources related to for example human capital through education within areas such as both general- and specific technological and scientific knowledge and competence, entrepreneurship, management and finance in addition to other types of resources such as access to financial capital and VCs (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, pp. 417-418). Furthermore, an emerging TIS needs to be able to mobilize essential and additional assets such as complimentary services, products and infrastructure.

Development of positive externalities: Developing positive externalities, also referred to as positive external economies, contributes to increase growth of a TIS through several ways. New entrants in a TIS can for example contribute to reducing or resolving uncertainties related to both technologies and markets. Furthermore, such new entrants contribute to strengthening other functions such as *influence of the direction of search* and *market formation* (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, pp. 418-419). These factors may also lead to further legitimation of the TIS in question. Moreover, new and increasing number of actors within a TIS can lead to an increase in political power. This power can be used to further increase the process of legitimation. Through an increase of legitimation of the TIS, additional functions can be positively affected. For example; *entrepreneurial experimentation*, *Influence on the direction of search*, *Market formation*, and *resource mobilization*. Furthermore, an increased number of new entrants and actors often leads to a greater amount of combinations related to *entrepreneurial experimentation* and *knowledge development and diffusion* (ibid). The function of *development of positive externalities* is not considered an individual or independent function. This is due to the fact that this function is more of a sum of the combination of the former 6 functions. Therefore, this 7th function can be considered an indicator of the overall functionality of the TIS. Since strengthening the other 6 functions will increase the function of *development of positive externalities*.

2.4.4 Assessing the functionality of the TIS

Assessing a TIS's functionality can be done by for example establishing its phase of development and identify inducement and blocking mechanisms and finally enable the analyst to formulate key policy issues.

The phase of development: Establishing the phase of development of a TIS can be applied to evaluate a TIS's functionality and performance**.** Bergek points to a difference between a formative phase and a growth phase. Differences in phases could entail varying functionality in coherence with the phase in which the TIS is currently in. A formative phase can be examined through a number of indicators; 1) time dimension, formative phases seldom lasts shorter than a decade. 2) Uncertainties related to markets, technology and applications. 3) Underdeveloped price/performance of products. 4) Unarticulated demand. 5) Economic activity and diffusion can be considered to be at a very low level compared to its estimated potential in regards to volume and finally, 6) weak positive externalities and a lack of positive feedback mechanisms (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, pp. 419-420). Once a TIS has developed through a formative phase, it becomes self-sustained and moves to the growth phase. The growth phase is characterized by a change in focus on expanding the system while at the same time facilitate technology diffusion and utilization at a large scale (ibid).

Identifying inducement and blocking mechanisms: The development of a TIS should only partly be attributed to internal dynamics of the system itself. Other factors, such as exogenous factors and context, play a major part of the TISs development. Moreover, the interaction between these internal and external factors also affects the development. Blocking mechanism are factors that are either internal or exogenous to the TIS which slows, impairs or otherwise hinders increased momentum and development for a formative TIS to become a more self-sustaining TIS in a growth phase. Such mechanisms can arise in the form of for example; 1) Lack of proponents and organizational power within the TIS in regards to the ability to facilitate legitimation, 2) customers lack of capabilities leading to a shortcoming of articulation of for example demand and 3) Networks' lack of ability to support the new technology through for example weak connectivity within networks, or on the other hand, tight networks connected through for example a *lock-in*[15] effect (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, Analyzing the functional dynamics of technologichal innovation systems: a schema of analysis, 2008, ss. 420-422). Inducement mechanisms are both internal and exogenous factors which enforces momentum and development of the TIS. An inducement mechanism can be amongst other aspects for example a mega trend (ibid). A trend along the lines of current growing concerns related to climate change, or for example increased spend and funding within a certain domain of R&D related to an emerging technology.

Specifying key policy issues: At this stage of the analysis, the analyst can begin with formulating key policy issues related to inducement- and blocking mechanisms which can contribute to further development of wanted functional patterns of the TIS in focus. Bergek argues that the goal of such policy should be to either increasing the number of- or strengthen inducement mechanisms and on the other hand reducing number of- or weaken blocking mechanisms (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, Analyzing the functional dynamics of technologichal innovation systems: a schema of analysis, 2008, s. 423).

2.5 Technological innovation systems in context

The TIS framework has been criticized by several scholars to be somewhat neglecting or failing to sufficiently address external aspects and surrounding contexts influencing a TIS (Markard & Truffer, 2008) (Bergek, et al., 2015). A discussion regarding main criticism and challenges related to the framework of this study, as well as how these aspects has been addressed, will occur in section 2.7.1 within this chapter. However, as a response to this criticism, as well as a measure to strengthen the analytical framework's capabilities to examine and increase understanding of the multiplex system, which is the Norwegian fast EV charging TIS, additional theoretical tools and frameworks will be combined with the scheme of analysis framework. Among other the Multi-level Perspective (MLP) as well as Bergek's conceptualization of contextual structures and interaction dynamics. This is because the concept of attempting to sufficiently describe the Norwegian fast EV charging TIS using only the scheme of analysis seems inadequate in terms of addressing the multitude of interplay and influence of underlying regimes, TISs as well as other forms of context related to for example

[15] *Lock-in* or *path-dependency,* explained by Smith as follows: "the ways in which technological regimes and innovation systems inhibit the innovation of technological alternatives, or prevent transition away from existing technologies." (2009, p. 16). See also Unruh 2000, 2002 and Unruh and Carrillo-Hermosillia 2006 for further elobaration of the term within a hydrocarbon regime lock-in.

incumbent laws, rulesets, political landscape and critical infrastructure that provides the premise and socio-technological sphere in which the focal TIS exists. In other words, as explained by Bergek: “The functions framework does not give much explicit attention to the dynamics of surrounding contexts.” (2015, p. 52). Furthermore, combining the scheme of analysis together with supplementary analytical frameworks is both recommended (ibid) and practiced by several scholars to strengthen analytical capabilities and provide in-depth empirical insights.

As to the conceptualization of contextual structures and interaction dynamics related to the use of the TIS-framework, this concept was developed to accommodate the already existing framework of TIS-analysis and its considerations towards contextual influences. Meaning that Bergek later has developed additional 4 aspects to strengthen the understanding of TIS-context structures and TIS-context interactions. Namely; *interaction between a focal TIS and other TISs, Interactions between a focal TIS and relevant sectors, TIS development in geographical context* and *Interaction between a focal TIS and the political context* (ibid).

2.5.1 Interaction between a focal TIS and other TISs

Bergek refers to this type of context as several emerging TISs interacting with the focal TIS in various ways. These interactions can for example be competitive or supportive (ibid). A competing interaction could be a TIS battling with the focal TIS for various strategic resources such as financial and human capital or market shares. Supportive interactions can for example be product efficiency development of batteries within a battery TIS, which potentially could support several TISs such as the power grid TIS, EV TIS and indirectly the overarching charging infrastructure TIS. Bergek describes the context of external TISs as similar to the context of the focal TIS: “They consist of technologies, actors, networks and institutions pertaining to a specific technological domain.” (2015, p. 55). The importance of various external TISs can vary and their relevance is thus an empirical question dependent on the specific study.

Interactions with contextual TISs can be complementary by for example providing higher product quality or lower prices in TISs which are connected by acting as for example up- or downstream suppliers. On the other hand, contextual TISs also pose possible bottlenecks by for example having complementary technology fall behind in development. Such TISs may also pose a threat as potential dependencies (ibid). Meaning that if they suffer external crisis, In terms of for example material shortages which leads to a cease in production, this will potentially harm the focal TIS. Other interactions that can occur and link TISs through the value chain are different forms of collaborations, such as joint ventures and acquisitions (ibid). There are also potential linkages and interplay between the focal TIS and horizontally related TIS (Bergek, et al., 2015, pp. 55-56). Such couplings can for example occur for TISs that produce similar output such as energy. Competing linkages can also occur, such as Equinor's entry in to RETs such as wind energy. Additionally, institutional linkages can arise for horizontally related TISs. Enova for example, The Norwegian Government's financial institution whom are responsible for executing the government's ambitions related to RETs and cleantech, provides financial resources to several sectors and industries. Including a multitude of different TISs. Innovation Norway is another example of an institution which is creating institutional linkages by providing financial support to numerous TISs on behalf of The Norwegian Government.

Finally, TIS-context interactions and the focal TIS's relative dependency and influence on external TISs tend to change over time. An emerging TIS is often more dependent on contextual TISs, while practicing a low degree of influence. However, this balance tends to change over time as the focal TIS increases its influence on contextual TISs and overcomes its dependencies (ibid). To summarize, interaction between the focal TIS and contextual TISs may lead to positive or negative developments in several of the focal TIS's functions, such as *direction of search, resource mobilization, knowledge development* and *knowledge diffusion* (ibid).

2.5.2 Interactions between a focal TIS and relevant sectors

To describe how a focal TIS may interact with relevant sectors, it is important to provide some context as to what the implications of the term *sector* entails:

> Sectors are composed of the same type of structural elements as TISs, but they rely on a larger set of technologies in different stages of maturity – and, consequently, on several different TISs to provide their overall function. They tend to exhibit high degrees of institutionalization in terms of well-defined division of labor and stable network relationships between supply-side actors, clear user practices, preferences and buyer-supplier relationships, sector-specific regulations and technological infrastructures. A sector therefore provides a quite stable context, which individual TISs either have to adapt to or try to change to their own benefit (Bergek, et al., 2015, p. 56).

Focal TIS interaction with a sector may occur in various ways. A TIS may also be subject to several sectors. An example of a sector-TIS interaction can be how a sector's incumbent actors may provide *lead users*[16] whom are potential candidates for contributing in developing new technologies or even co-create solutions specific to their needs. Furthermore, Sector-level networks can affect and guide the functions of *legitimation* and *direction of search* of all TISs within the sector by for example lobbying and influencing political agendas (ibid). *Shared technological assets*, including for example physical infrastructure such as the power grid or soft infrastructure such as joint sectoral knowledge, often tends to serve incumbent technologies (ibid). *Norms and values* related to a specific sector may also be a potential source of influence on TISs. Lastly, and perhaps the most pertinent, *sectoral-level institutions* provide a wide array of potential ways of influencing and affecting TISs. Including aspects such as policies, influence framework conditions such as for example liberalization policies in infrastructure sectors can greatly affect the function of *market formation*, as well as influencing incumbent actors' dealings with new technologies. Such dealings can potentially affect *the direction of search* within a TIS. These two TIS functions are also potentially influenced to a significant degree by for example sector laws, standards, regulations and economic support systems (Bergek, et al., 2015, p. 57).

2.5.3 TIS development in geographical context

As a consequence of the fact that structural TIS components exists somewhere within a certain space, TIS boundaries will often to some degree coincide with territorial limits such as for example regions and nations. Furthermore, soft- and physical infrastructure would exist where a sector or a technology is currently placed. Making this location a viable place to search for relevant favorable conditions for a firm, TIS, industry or sector to establish itself (Bergek, et al., 2015, p. 58). This leads to the concept of relating geographical context to a TIS by describing its boundaries in addition to identifying external links that may exists between a TIS and specifically locally occurring resources. In some cases, dealing with geographical context can be rather straight forward if relevant technological, sectoral and political context-structures overlap a specific territory, like a nation (ibid). Which in many ways is the case for the focal Norwegian fast EV charging TIS, as we shall se.

[16] Lead users: "they are ahead of the majority of users in their populations with respect to an important market trend, and they expect to gain relatively high benefits from a solution to the needs they have encountered there." (Hippel, 2005, pp. 5-6)

2.5.4 Interaction between a focal TIS and the political context

Interactions between the focal TIS and the political context is highly relevant as it to a large extent embodies institutional alignment. Including influence towards norms, beliefs and regulations which can lead to beneficial alterations within for example established governing soft infrastructure. Leading to the fact that political context surrounding a TIS is greatly influential to the TIS's development. In short, the characteristics and significance of the political context can be summarized as follows ;

> structural couplings are created in the form of aligned institutions which enable the provision of specific resources that are essential for the further maturation of the TIS (Bergek, et al., 2015, p. 59).

Firms compete over both markets as well as political influence related to the surrounding political- and institutional context. On the other hand, firms also tend to collaborate in order to legitimize as well as manipulate the political context to their favor. Collectively gaining access to valuable resources. Such manipulation may, according to Bergek, involve: "Building legitimacy, creating positive expectations and influencing the adoption of regulations that shield markets and nurture innovations." (2015, p. 60). In this context, firms and networks whom engages in aforementioned activities represents the structural couplings between the TIS and the political system. The political systems, which provides the political context for TISs, differs to a high degree in for example regions or nations. therefore, such context tends to surpass the boundaries of sectors and technologies (ibid).

2.6 The multi-level perspective

Conceptualization of contextual structures and interaction of TISs provided by Bergek enables an analyst with some additional and complementary analytical tools to improve empirical capabilities when applying the scheme of analysis to a TIS. However, the surrounding context of a TIS can often be as complex as the TIS in question. This leads to a great need for a suitable and tailored framework to enable formalization, analysis and eventually a thorough understanding of a TIS and its surrounding context. Furthermore, use of- and the relationship between terms like sectors, TISs and regimes becomes relevant notions which contributes to provide additional context to the variations of interplay and significance of the various structural components as well as the surround context of a TIS. Therefore, I have chosen to include relevant aspects of the MLP-framework as part of the overarching analytical framework of this study.

In 2008, Markard and Truffer attempted to consolidate the literature on TISs and The Multi-level perspectives-approach (MLP). Their efforts resulted in a framework rooted in similarities, conceptual overlaps and perceived weaknesses and strengths. The MLP-framework emphasizes the notion that technological transformation occurs as a result of interaction between 3 key concepts; socio-technological regimes, niches and the socio-technological landscape (Markard & Truffer, 2008). The combined framework of MLP and TIS is considered an integrated overarching framework for understanding large socio-technological change and radical innovation processes, such as the emergence and development of for example The Norwegian fast EV charging TIS.

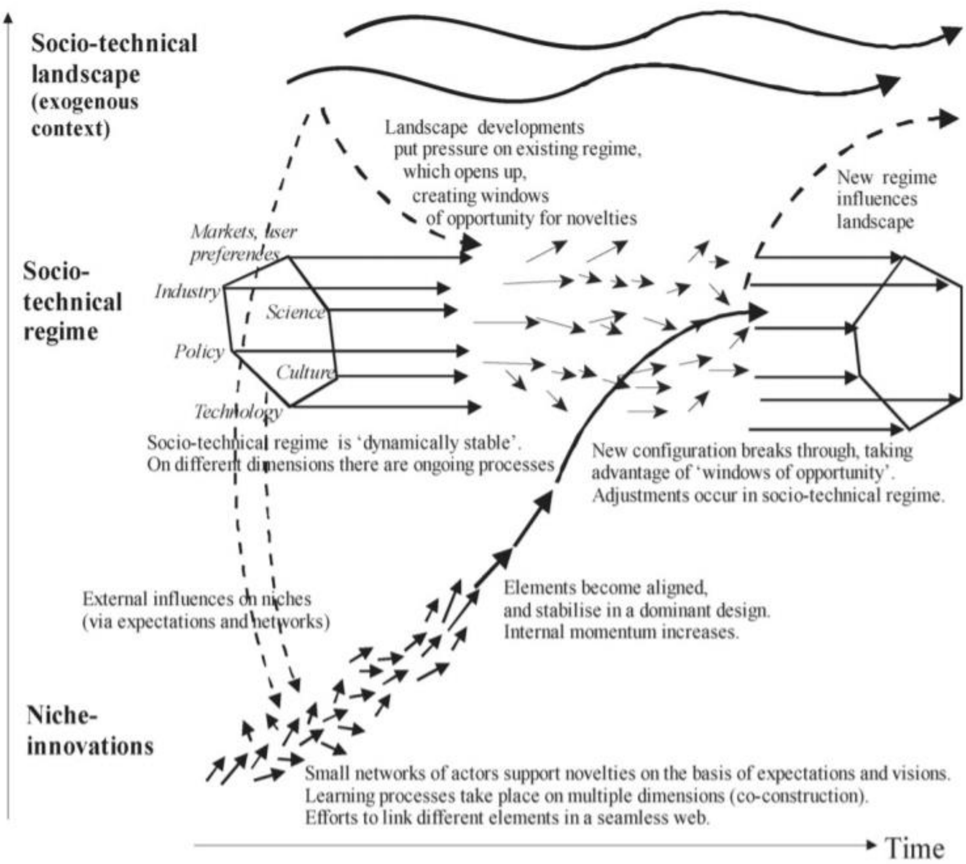


Figure 2) The Multi-level perspective.The figure describes the relationship and dynamics between the socio-technical landscape, the socio-technical regime and niches according to Schot and Geels interpretation of the framework in 2007 (Schot & Geels, 2007, p. 401).

2.6.1 The notion of regimes

At the base of the key concepts within MLP is the notion of technological regimes. Also referred to as socio-technological regimes. Rip and Kemp's definition of these type of regimes is considered central in the transitions literature and their definition will provide context when referring to the term in general:

> The grammar or rule set comprised in the complex of scientific knowledges, engineering, practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of technology (Kemp, Rip, & Schot, 2001, p. 272).

Note that for example actors and networks is not included in the definition and that the transitions literature contains variations in the application, use of- and even understanding of socio-technological regimes or systems. A distinction is often made toward regimes being more related to a coherent ruleset, and a TIS being perceived as having more texture related to its considerations towards for example actors, networks and institutions within a system (Markard & Truffer, 2008).

Since the notions and definitions of socio-technological regimes, socio-technological systems and technological innovation systems is intertwined, several definitions and aspects has been formulated within the concept of regimes and systems in the transition literature. In the case of regimes we have Nelson and winter's regime notion from 1982, Malerba and Orsenigo's aspects from 1993, or Hoogma's broader definition similar to the concept of a TIS in 2002 (Hoogma, Kemp, Schot, & Truffer, 2002). These overlapping and varying definitions and applications of the regime term can quickly become a challenge when reviewing and applying the literature. Furthermore, the above definition of socio-technological regimes is considerably broad and could be even more specific to make the notion more applicable. To clarify and increase understanding of use of the term, the following definition developed by Markard and Truffer will be applied combined with the context of the above definition when referring to regimes:

> A coherent, highly interrelated and stable structure at the meso-level characterized by established products and technologies, stocks of knowledge, user practices, expectations, norms, regulations, etc. (p. 603).

In short, a socio-technological regime can be considered a dominant stable production structure (Markard & Truffer, 2008, p. 605). A structure that is stable though not without changes. However, these changes are not radical enough to significantly influence or change the main characteristics of the established dominant production structure. This resistance to fundamental change exists due to for example relations between industry, associations or other political or lobbying organizations. Radical innovations tend to occur on the fringes or outside of established regimes (Geels, 2007, p. 128), often within for example niches.

2.6.2 Niches

Niches, commonly referred to as incubation rooms or protected spaces, serve as the local level in which the innovation process can take place. Niches enables novel technologies and new socio-technological practices to occur and develop while being isolated and protected from the vigorous competition and pressure within what can be considered as normal regimes and markets (Markard & Truffer, 2008, p. 605) Hoogma defines niches as follows:

> A discrete application domain (habitat) where actors are prepared to work with specific functionalities, accept such teething problems as higher costs, and are willing to invest in improvements of new technology and the development of new markets (2002, p. 4).

Niches and regimes share a number of communalities. While on the other hand, niches and regimes differ to a large extent when comparing scale and level of aggregation. For example, a niche is considerably smaller in terms of size and is therefore considerably less stable than a regime (Markard & Truffer, 2008, p. 606).

2.6.3 The socio-technical landscape

The landscape concept can be described as external heterogenous factors that influences both niches and regimes. Geels provides a central definition of this key concept within the transition literature; *"*A set of heterogenous factors, such as oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, environmental problems." (2002, p. 1260). Furthermore, the concept can be summarized as background- or residual variables that affect transition processes but can be considered as autonomous and independent when it comes to the variable's origin and agenda. In short, the landscape can have an impact on innovation and innovation processes but is not necessarily affected by innovations or its processes (Markard & Truffer, 2008, p. 606)

2.7 A tailored analytical framework

Initially, a discussion regarding strengths, weaknesses and main criticisms related to the tailored analytical framework will be conducted in this section. Followed by a comparison and discussion of the aspects, terms, analytical tools and frameworks expounded upon in this chapter. Which seems to be in order to explain why and how the MLP- and the TIS-approaches complement each other. Lastly, I will discuss the practical application of the tailored analytical framework in the context of analyzing the Norwegian fast EV charging TIS and answering the research questions of this study.

2.7.1 Strengths, weaknesses, and main criticisms

One of the strengths of the MLP-approach is its ability to explain transition and innovation processes regarding interactions and relationships between rulesets and other stabilizing factors within a regime. Furthermore, the MLP-approach also considers the radical innovations often occurring at the niche level as well as bearing in mind external factors and shocks within the landscape level. However, the approach is less powerful when it comes to describing and understanding the role and interaction of various actors within the internal functions and dynamics of a system (Markard & Truffer, 2008). This weakness is rooted in the lack of analysis and understanding regarding distribution of for example resources among actors, which again is related to the formation of networks as well as innovation potential of different actors. This weakness arguably arises from the MLP's focus on emerging novelties within niches. Markard and Truffer argues that this weakness raises 3 issues; There is a gap in terms of aggregation and process complexity related to niches and regimes. Little explanation in terms of dynamics beyond the niche level exists, while the analytical framework within MLP related to investigating innovation dynamics at the niche level are arguably inferior compared to TIS's analytical tools. lastly, the understanding of the role of actors and their strategies have received little attention within the conceptualization of niches (Markard & Truffer, 2008, p. 609).

When considering the weaknesses of the MLP-approach, the TIS-framework can be viewed as analytically superior in several ways. More specifically, understanding and explaining structure and function as well as investigating firm strategy and agency (Markard & Truffer, 2008, p. 610) On the other hand, the TIS-framework is arguably not equally applicable for understanding far-reaching technological transitions. Markard and Truffer argues that the success of innovation within the TIS-approach is mainly regarded as a result of the performance of related innovation systems (ibid). This entails an inward perspective when understanding the success of innovation. Such a perspective can lead to short-sightedness when considering forces and influences which occurs outside the systems of analysis. For example, external institutions may be deemed as blocking mechanisms and barriers when in reality, their role is far more intricate and significant (ibid). This is where the MLP-approach seems empirically stronger in terms of understanding the role of institutions, incumbent actors, difficulties related to change and other stabilizing and influencing factors within the surrounding context of a TIS.

In general, the strengths and weaknesses within the TIS- and MLP-approaches makes the combination of the two frameworks highly complementary (Markard & Truffer, 2008). Furthermore, the addition of Bergek's conceptualization of contextual structures and interaction dynamics should contribute to further strengthen what will be referred to as *the tailored analytical framework* applied within this study. A framework specifically developed to examine and understand the Norwegian fast EV charging TIS and its surrounding context while considering the inherent strengths and weaknesses of its analytical tools and concepts.

2.7.2 Comparing and discussing concepts, terms and analytical tools

In general, both the expanded TIS-framework and the MLP-approach share several communalities. For instance, both frameworks consider to some degree actors, institutions and networks (Markard & Truffer, 2008). However, significant differences exist. In terms of application in this study, there also exists considerations related to how the various terms from the MLP- and TIS-methodologies will be applied. Additionally, there is a variance in the degree of utilization when it comes to the aspects that comprise these analytical frameworks. Meaning that some, rather than all, of the aspects of the methodologies will be applied to this study.

The notion of sectoral systems of innovation (SSIs) has not been included in the analytical framework. Even though the notion of SSIs can be considered central throughout the transitions-literature. This is because the term SSI often serve the same purpose as the regime-terminology. Furthermore, the regime-term has frequently been applied similarly as the SSI-term throughout the literature. Especially in broad empirical applications (Markard & Truffer, 2008, p. 608). An SSI can include products, processes and technologies. While on the other hand, regimes can be considered, in its most narrow application of the term, more of an understood and stable set of rules. However, when implying a broader application of the regime term, it is considerably similar to the concept of SSIs (ibid). For example, regimes and SSIs are often defined at the same level of empirical aggregation and considers industries and sectors. One of the differences between SSIs and regimes is the fact that an SSI may consider several regimes.

In this specific study, the notion of regimes contributes to provide context of how established and stable rulesets affect firms, TISs and sectors. Therefore, the regime terminology seems preferable to the SSI-concept. Additionally, a regime-oriented application enables an arguably more adapted analytical concept better suited to answer the research questions of this study. This is because established rulesets to a large extent contributes to explain several aspects related to the surrounding and influencing context of the Norwegian fast EV charging TIS. Furthermore, preferring the regime-notion over for example incorporating both notions with similar meanings, should contribute to simplify the analytical framework and its application.

Differences, necessary considerations and adaptions also exists within the analytical concepts of niches and TISs. A mature TIS can for example be considered more regime-like as well as having an ability to incorporate itself into several sectors (Markard & Truffer, 2008). This fact can arguably be observed within the case of the Norwegian fast EV charging TIS. Even though this focal TIS is considerably new and in many ways immature, it is still very much connected and dependent on mature and developed TISs, regimes and sectors. For example, the transportation- and the energy sector, the power grid TIS and associated governing regimes. In terms of the level of aggregation related to TISs, an emerging TIS can include several variations of application contexts related to a novel technology. This means that the level of aggregation for an emerging TIS often is lower compared to a mature TIS (Markard & Truffer, 2008, p. 608). Niches on the other hand, are often the lowest aggregated analytical concept when comparing the TIS- and MLP-approaches. This is due to the niche concept's tendency to refer to as few as one technology application context (Markard & Truffer, 2008). A relevant example is the Norwegian fast EV charging TIS, which could, at least at some point, have been referred to as a niche within the overarching Norwegian charging TIS. This becomes evident when comparing the application of fast EV charging technology with all application contexts of e-mobility charging infrastructure technology. Such overarching application of charging technology may include technology contexts such as; mobile charging options, private home charging or other not publicly available options such as office parking charging. Furthermore, the overarching Norwegian charging TIS encompasses other forms of application contexts within transportation such as sea- and air transportation. Both the focal TIS as well as the overarching Norwegian charging TIS may therefore imbed itself into several sectors and be governed and influenced by a number of different regimes. As to the relationship between the use of the TIS concept together with the concept of regimes and niches, Markard and Truffer states the following;

> While regimes generate incremental innovations that strengthen the regime, niches create and protect radical innovations, which may lead to destabilization and far-

> reaching changes in established regimes. TISs, on the other hand, do not make a difference between radical and incremental innovations, i.e. they – implicitly – embrace the production and the innovation part. The TIS concept therefore can be applied to both, regime- or niche-like empirical situations (2008, p. 608).

In short, Markard and Truffer argues that a TIS can be considered niche or regime-like based on the TIS's maturity (ibid). Meaning that a formative TIS can be considered niche-like as it will protect and generate innovations related to the technological application contexts within the TIS (Markard & Truffer, 2008, p. 609). Much in line with Edquist's general characterization of innovation systems (2005). While on the other hand, a more developed and mature TIS can be considered to progress gradually towards a regime as it incrementally transforms into a stable set of governing and influencing rules and aspects (Markard & Truffer, 2008). Much in line with Bergek's considerations on the dynamics between influencing and interacting contextual structures related to a TIS, as well as the TIS's influence on its surrounding context (2015).

Based on aforementioned aspects in combination with strengths and weaknesses related to the various analytical methodologies within this chapter, the application of *the tailored analytical framework* seems sound and should provide valuable empirical insights when examining and attempting to understand the Norwegian fast EV charging TIS, its functions, functionality and surrounding and influencing context. The assumptions regarding suitability of the tailored analytical framework is based on the following considerations: the framework is compatible with the concept of regimes, niches and the surrounding context related to a TIS. Technology serves as the point of departure for analysis. It is tailored to answer the research questions of this specific study as well as being in line with delineations, scope and the case of the Norwegian fast EV charging TIS. It embodies a system-based rationale while also emphasizing the role of innovation within *the production part* and not necessarily *the innovation part* In line with Markard's & Truffer's recommendations when applying the integrated framework (Markard & Truffer, 2008, p. 610).

2.7.3 Applying the tailored analytical framework

In short, the expanded TIS-framework and the MLP-approach represents different views and methodologies for analyzing processes of innovation and socio-technological transformations within a system context. Since the concepts and notions within the different approaches are somewhat overlapping or intertwined, a consideration as to how the tailored analytical framework will be applied is in order. Markard and Truffer developed tentative overarching guidelines as to how to interpret and apply the integrated framework. Guidelines which are highly applicable for the tailored analytical framework of this study as it is largely based on the integrated framework. Briefly summarized, Markard and Truffer offers 3 main recommendations; Negate the weaknesses of both approaches mentioned in section 2.7.1, follow the guideline for minimum conditions related to defining a TIS as per section 2.4.1 and clearly distinguish and apply notions and terms from the 2 aspects and explain their interplay as per section 2.7.2 above (Markard & Truffer, 2008). Furthermore, Markard and Truffer developed a model explaining the interplay between the different notions and aspects of the combined framework;

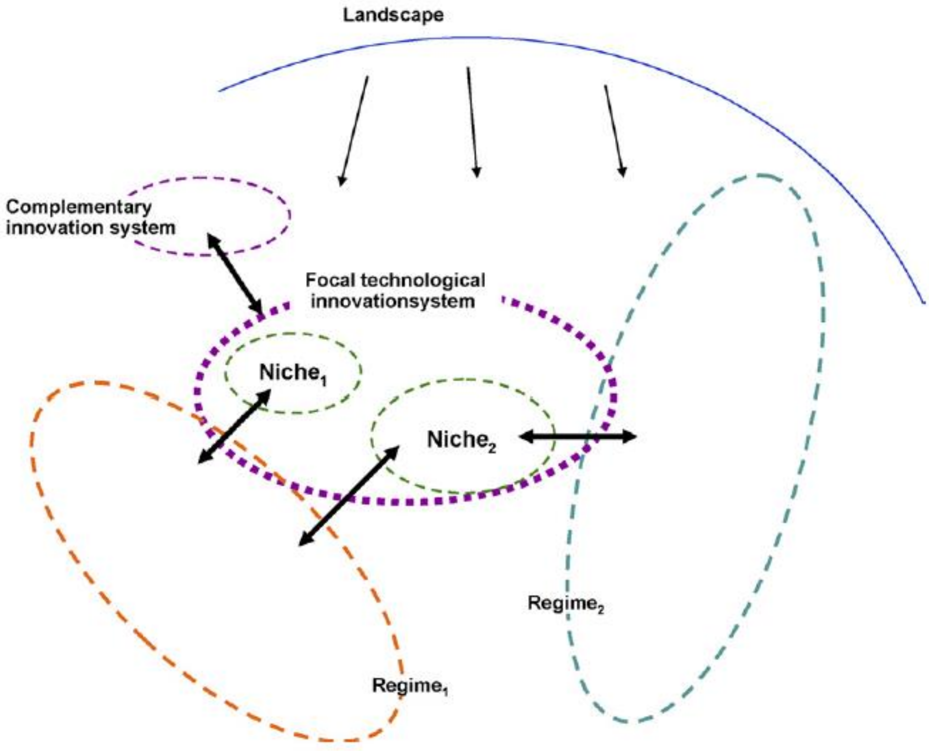


Figure 3) ***The technological innovation system and interactions with the conceptual elements of the multi-level framework.*** **The figure illustrates the interplay between the TIS- and MLP-framework. Furthermore, the figure illustrates how a TIS can contain several niches, be influenced by more than one regime and relate to other complementary innovation systems. The figure also illustrates how landscape factors influence all other concepts within the methodology** (Markard & Truffer, 2008, p. 612)**.**

Since the above model is based on the integrated framework, consisting of Bergek's scheme of analysis as well as Markard's and Truffer's considerations of MLP- and the TIS-framework, I have chosen to develop a model that describes the relationship between the notions and analytical tools that encompasses the tailored analytical framework which serves as the overarching analytical framework applied within this specific study;

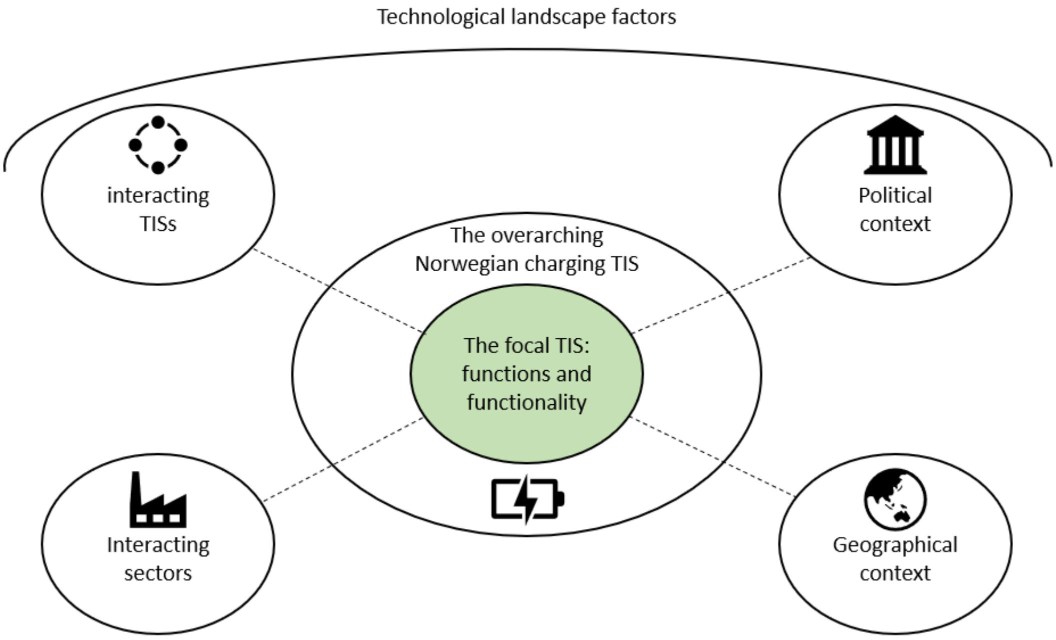


Figure 4) ***The tailored analytical framework.*** **Inspired by Markard's and Truffer's illustration of the interplay within the concepts and notions of the integrated framework** (Markard & Truffer, 2008, p. 612)**. However, adaptations have been made to reflect the tailored analytical framework that will be applied to analyze the focal TIS of fast EV charging in Norway. The framework and its application are aligned with the scope, research questions and aspirations of this study. Furthermore, the framework and its application consider the iterative process of increased understanding in regard to both the framework and the topic of this study.**

As can be observed by examining figure 4, the focal TIS exists within the overarching Norwegian charging TIS. Furthermore, the influencing and interacting surrounding context of both the focal TIS as well as the overarching charging TIS is illustrated by their relation to the socio-technical landscape and interaction with the 4 aspects of structural context.

To summarize, the tailored analytical framework aspires to enable analysis and increased understanding of the Norwegian fast EV charging TIS by combining relevant aspects of the scheme of analysis, MLP and the conceptualization of contextual structures and interaction dynamics. The framework is based on strengths and weakness, theoretical contexts within this chapter and an aspiration for a simplified and relevant framework applicable for answering the research questions of this study in depth. A combination and application of the scheme of analysis, MLP and the conceptualization of contextual structures and interaction dynamics in this way is seemingly novel. Therefore, this study can be considered conceptually exploratory. Finally, a more thorough explanation of the practical process of applying the framework to the topic and research questions of this study through for example the research design, will be expanded upon in the next chapter.

3. METHODOLOGY

The topic and general context of this study was identified at an early stage within the process of developing this thesis. The topic of electrification of transportation in Norway was chosen on the basis of its relevancy related to global climate challenges in combination with ongoing national efforts and political debates. Additionally, the topic also contains interesting aspects of innovation related to diffusion and utilization of emerging technologies such as EVs and fast EV charging. Furthermore, by conducting an initial literary review of EV- and EV charging research, little was found in terms of conceptualizing barriers and drivers in connection to increase adoption, diffusion and utilization of such electrification technologies. Especially not within the context of Norway's current efforts and initiatives. Thus, a potential knowledge gap was found within an aspect as fundamental as concretizing challenges in the form of barriers which could potentially reduce or hinder adoption, diffusion and utilization of a specific technology such as fast EV charging in the context of Norway. Potentially slowing down the transition from a fossil fuel-based economy to a green one. Thus, it would be of interest to investigate underlying drivers which explains why and how the need and initial market for this particular technology has developed within for example Norway. Norway is of course of particular interest due to its already far reaching and impactful electrification transition within transportation. As it consequently serves as a learning space and source of valuable knowledge and knowledge development for various national and global actors and entities.

3.1 Qualitative studies

Initially a wide scope along the lines of investigating charging technology globally, as well as across sectors, regimes and industries via for example supply chain- or component analysis, was contemplated. However, due to challenges related to the share complexity of the potential scope of the research, in addition to prevalent relevance of several central concepts such as systems of innovations connected to development, generation, adoption, diffusion and utilization of electrification technology, a realization quickly emerged as to what degree or delimitation one or more aspects of for example electrical transportation charging technology could feasibly be studied through a system-lens. In line with the understanding that qualitative studies are being considered an approach which is very much concerned with understanding the meanings of which people may attach to a phenom (Snape & Spencer, 2003) Thus, transition theory and system analysis as analytical tools and concepts combined with qualitative case study-methodology, seemed increasingly apt to develop a feasible study of the social phenom of diffusion and utilization of one specific application context of fast charging technology within a context such as the case of development and use of fast EV charging stations in Norway. Since qualitative studies are more concerned with investigating *how* something is said, used, interpreted, done or developed, rather than quantitative studies which arguably focuses more along the lines of *how many* or *how much* (Brinkman & Tanggaard, 2010). Additionally, the qualitative case study-methodology arguably aligns nicely with the tailored analytical framework consisting of TIS and MLP. Since, system analysis and case study-methodology in many ways strives to achieve the same goal of understanding a complex phenom in addition to be a common and proven approach within social studies, including disciplines such as technology, innovation and economics.

Yin defines a case study as an empirical inquiry that; “investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.” (Yin, 2009, s. 18). Qualitative methodologies such as case studies are also highly applicable and relevant when studying social phenomes where the researcher has little control (Yin, 2009, s. 4). Furthermore, case study-methodology applies 3 highly relevant aspects related to sources of evidence that seems especially applicable to the topic of this study, as well as the concept of system analysis; analyze happenings of the past, applying direct observations as well as expert interviews with people whom were involved in relevant events (Yin, 2009, s. 11). Additionally, applying other approaches such as quantitative methodologies purely drawing upon for example survey data or various statistics would arguably not suffice to answer the research questions of this study. Since the goal of this study is to increase understanding as to *how* the system in which engages in diffusion and utilization of fast EV charging technology functions, as well as understanding *what* mechanics and aspects supports and impends this system, and finally understand the role and contribution of The Norwegian Government in relation to the 2 former aspects.

3.2. Data collection

Data collection has been a continuous and iterative processes alongside the development of the study as well as my own understanding of the topic and the case of fast EV charging in Norway. The process of data collection has been solved by applying various strategies and looking to several forms and sources of data. For example, initial understanding of the topic was formed through document analysis and consumption of various reports in addition to strategic and governing documents issued by the Norwegian government. Furthermore, on the basis of my newfound understanding of electrification of the Norwegian transportation sector and its involved industries, sectors and markets, a Snow balling approach was applied by for example reaching out to my network, contacting central actors within structural components of the focal TIS and increasing my skill in acquiring relevant and supportive information through various forms of research and reports trough for example google scholar[17] and UiO: Oria[18]. In short, 3 main strategies and sources of data collection was applied; document analysis, expert interviews and databases resulting in descriptive data.

3.2.1 Document analysis

The documents which has been analyzed and applied within this study can be grouped within 2 main categories. The first one being related to analytical, theoretical and methodological frameworks. The second one encompasses topical documents related to electrification of the Norwegian transportation sector and the process of analyzing and discussing the focal TIS and the research questions of this study. Including documents and information detailing technologies related to this particular transition such as EVs and EV charging technology. Within the first category of analytical, theoretical and methodological documents, academic research encompassing innovation, transition theory and the subsection of system analysis has primarily been applied to conceptualize and understand the Norwegian charging infrastructure network as a TIS and develop the tailored analytical framework. The second category entails technology specific research in terms of industry and market development, annual reports and articles published by relevant actors, various forms of reports and papers, nationally strategic and governing documents and publications, laws, regulations and standards, hearing reports and related documents such as submitted inputs in relation to hearings and participation in political debates and networks.

3.2.2 Expert interviews

Semi-structured expert interviews were conducted to acquire an in-depth understanding of the focal TIS by serving as an instrumental source throughout the analysis in combination with other complementary sources. Informants were recruited through first and foremost sharing my initial activities and tentative thesis on LinkedIn, asking for relevant bodies of expertise of

[17] https://scholar.google.com/
[18] https://uio.oria.no

which I could contact. Trond Kristiansen, Ole Gudbrand Hempel and Kristian Lima were recruited in this fashion. Furthermore, initially recruited informants contributed extensively by also referring me to their extended networks. Jan Pedersen was recruited in this fashion. Finally, I came in contact with Circle K charge, Synnøve Grøndahl and Einar Gotaas by taking direct contact with central actors of the focal TIS such as associations and CPOs.

The knowledge and insights represented by the 7 informants is broad and extensive and can be referred to as a *techno-epistemic network*. A concept which can be defines as: "A network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain" (Haas, 1992, s. 3). For example, Einar Gotaas has extensive analytical and political experience from various private and governmental actors in addition to be formally educated as an economist. Ole Hempel has worked as Country Manager for fast EV charging in Fortum Charge & Drive and is currently acting as Regional Manager, Charging Nordics at Tesla. Jan Pedersen formerly worked as Executive Vice President of Agder Energi for over 10 years and was also head of the project that is now Grønn Kontakt. See table 4) below for an overview of informants.

Name	Organization	Role	Date of interview	Interview
Anonymous	Circle K Charge	Part of management team	15/9 - 2020	Interview 1
Jan Pedersen	Agder Energi	Director	15/9 - 2020	Interview 2
Ole Gudbrand Hempel	Tesla	Regional Manager, Charging Nordics	7/9 - 2020	Interview 3
Synnøve Grøndahl	The Norwegian EV Association	Advisor	17/9 -2020	Interview 4
Einar Gotaas	Drivkraft Norge	Chief Advisor	10/9 - 2020	Interview 5
Trond Kristiansen	The County Municipality of Agder	Advisor Climate and Energy	11/9 - 2020	Interview 6
Fredrik Lima	Zaptec	VP Europe	10/9 - 2020	Interview 7

Table 3) *Overview of informants.* The table shows an overview of recruited and interviewed informants, their affiliated organization, role and date of interview.

Due to the quality of the interviews combined with the fact that findings and feedback formed distinct patters by in many ways pointing to the same overarching concepts, I decided to end my interviews at 7. Although I had access to additional informants, it is my opinion that I had gathered enough data to conduct a thorough analysis and that it would be sensible to spend my resources elsewhere in relation to the study. The interviews lasted between 30 and 90 minutes and was semi-structured in the sense that varying emphasis was given to different parts of attached interview guide within each interview. The variance was based on the individual informant as well as my incremental increase in understanding- and process of outlining the focal TIS and its surrounding and influencing context. The interviews was recorded and transcribed in accordance with agreement with the informants.

3.2.3 Databases and descriptive data

A few instances of databases and statistical data has also been applied within this study. Through collaboration with The Norwegian EV association, a copy of relevant content within the Nobil Database[19] was made available. This data has been compiled and aggregated in excel to initially map owners, operators and technologies within the Norwegian charging market. Furthermore, participation lists from relevant networks such as The Nordic EV summit[20] was acquired from their websites. This data was also compiled, aggregated and applied to much of the same avail as the Nobil Database. Finally, statistical data procured on basis of the Nobil Database, made available by The Norwegian EV Association[21], was applied to provide descriptive data of for example number of- and market development of EVs and various categories EV chargers throughout Norway.

3.3 Research design and data analysis

Data analysis has been based on applying sources and findings to the tailored analytical framework. This was completed by first and foremost developing a research design based on the innovation systems literature by identifying applicable tools and frameworks to conceptualize and analyze the topic of this study. Furthermore, these theoretical and analytical concepts were adapted to the specific case of the focal TIS within the context of Norway, in addition to the scope and limitations of this study by developing the tailored analytical framework. The following process was then developed in terms of research design.

[19] https://info.nobil.no/
[20] https://nordicevs.no/2019-participant-list/
[21] https://elbil.no/elbilstatistikk/

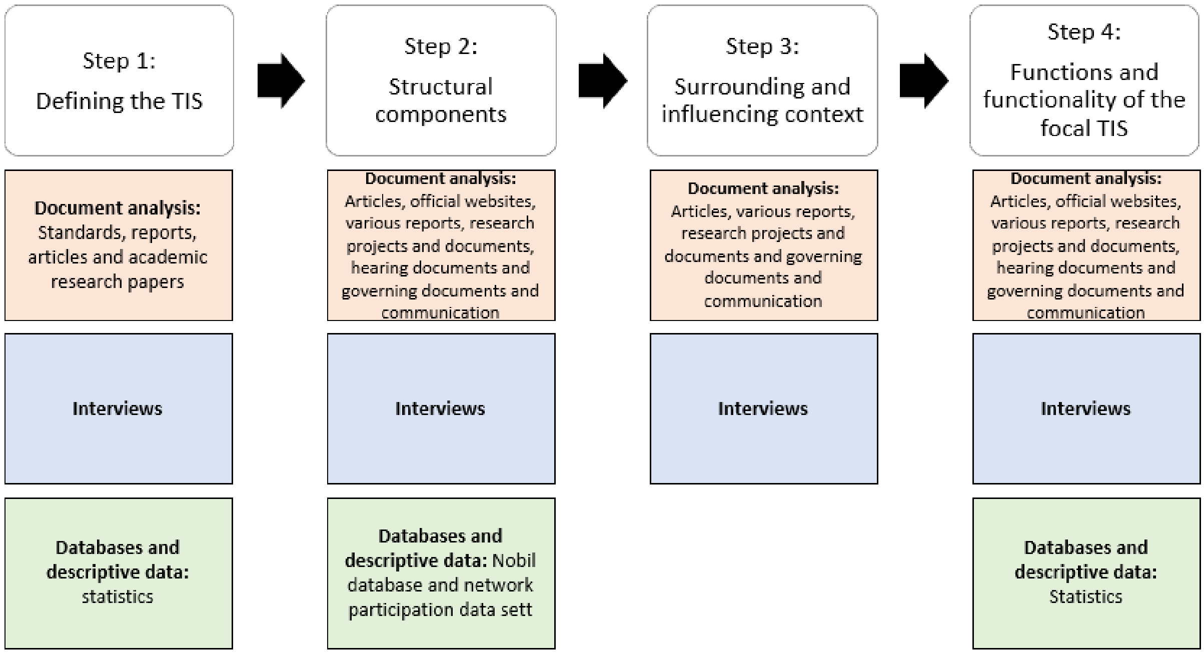


Figure 5) ***Research design.*** **The figure illutrates the research design related to this specific sudy. Empirical strategies, data sources and their application thorughout the process of analysis has also been outlined to illustrate where and how they have been applied to the tailored analytical frameowrk throughout the analysis.**

In terms of data analysis, findings and relevant citations from the interviews were grouped within relevant steps of analysis and categories of the tailored analytical framework. Strategic and governing state documents such as the NTP, research and relevant communication such as hearing reports and action plans were analyzed to describe and understand several of the structural components as well as contribute to explain several functions of the focal TIS. Explicit statements, role and contribution of the Norwegian Government and its subjected entities was also derived from these documents in terms of outlining their role and contribution in relation to fast EV charging diffusion, utilization and commercialization. In general, documents and interviews were instrumental in all steps of the research process. Databases and descriptive data such as statistics were particularly relevant to initially map relevant structural components as well as describing market development and the state of adoption, diffusion and utilization of EV- and EV charging technology in Norway.

3.4 Reliability and validity

Reliability and validity are used to evaluate the quality of a specific study (Ringdal, 2013). Historically, these concepts has been developed within natural sciences and has therefore been considerably focused on quantitative research and its ability to generalize findings between studies of for example a representative sample onto a significantly larger population. Due to historic success of the concept of quantitative studies by for example providing tangible, measurable and reproducible results, the applicability and relevance of related reliability and validity within qualitative studies has been challenged (Ritchie & Lewis, 2003). The skepticisms is based on the lack of ability to recreate the exact study since, the quantitative methodology is fashioned in a way that would make reproduction arguably irrelevant or impossible. Often due to research objects being too unique or complex to be able to make significant generalizations between studies (ibid). Even though not all aspects of the traditional understanding and application of reliability and validity may be applicable to this exact qualitative case study, applying Yin's concepts of reliability and validity should contribute to ensure a higher quality in relation to this specific study by providing considerations within for example data collection, analysis and research design. Yin presents 3 aspects of validity; internal-, external and construct validity (Yin, 2009). Internal validity is related to casual analysis and will therefore not be addressed.

3.4.1 Reliability

Reliability entails a researcher's adherence to similar methodology as previous researchers in addition to the similarity between their findings and conclusions (Yin, 2009, s. 45). Due to the characteristics of quantitative studies, high degrees of reliability is challenging to achieve. This has also been a criticism towards much of the system based analytical framework, where generalization and comparability of various studies is arguably low. Creating difficulties related to extracting value from system theory-based research by applying and comparing studies in relation to for example policy development (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008) (Markard & Truffer, 2008). In short, considerations related to reduce errors and biases within qualitative studies should be made by for example illustrating procedures for data collection and analysis. In terms of adhering to a achieve some degree of reliability, a governing interview guide was established and served as a template for collection all of the data from the interviews. Additionally, only one informant expressed a need for relative anonymity, arguably contributing to increase reliability as the latter 6 informants did not ask for anonymity when offered. Furthermore, the interviews were audio recorded and transcribed. Later, their findings and citations were compiled in accordance with the research design. Creating a procedure which in many aspects could be reproduced in line with some degree of reliability. The interviews and recordings will remain stored and potentially accessible if needed. All informants were given and signed a document entailing use of- and their rights related to the interviews and recordings.

3.4.2 External- and construct validity

Construct validity refers to establishing a sufficient set of measures in order to approach the specific case of a study, including for example the use of several sources and methods of gathering data and evidence (Yin, 2009, s. 42). In order to attain the highest possible level of construct validity, I have attempted to support my empirical findings by referring to more than one source of data, as can be observed in figure 5) above. For example, structural components were analyzed by applying several strategies of data collection and sources such as interviews, databases, descriptive data and various forms of documents and document analysis. Arguably contributing to a high degree of construct validity. However, some prioritization and considerations as to number and characteristics of for example informants had to be made. Only one of the informants are currently representative of significant actors such as for example The Norwegian Government, in this case a county municipality. However, the role of The Norwegian Government has arguably been sufficiently addressed by having its interplay, influence and contribution in relation to the focal TIS described by several informants with varying backgrounds, roles and experiences. Additionally, this aspect of the structural components and its interplay has been additionally addressed by applying several methods and sources of data, such as analyzing various governmental documents.

External validity addresses a study's ability to be generalized alongside similar studies and findings (Yin, 2009, s. 43). As aforementioned, the challenge related to generalization of studies based on system-analysis has been a frequent topic within the system theory literature. The huge differences between systems, sectors, industries, markets and regimes combined with the variances in methodical and analytical approaches and application make for significant complications when attempting to generalize such studies and their findings. Furthermore, delineation and scope of a specific TIS may greatly vary between studies, even though they are based on the same theoretical and analytical concepts. However, since this study applies the system theory framework and adheres to its guidelines, it can be argued that method and findings is generalizable to some extent. On the other hand, generalization of findings is not the main goal of this study. This study aspires to contribute to expand understanding and conceptualization of technological innovation systems by conceptualizing, analyzing and discussing the context in which barriers and drivers related to further electrification of Norwegian transportation through charging technology is taking place. Therefore, this specific study is not necessarily overly concerned with all aspects and considerations of validity.

4. ANALYSIS: THE NORWEGIAN FAST EV CHARGING TIS

In this chapter, empirical findings will be presented within 4 sections. Including the processes of defining and delineating the focal TIS, analyzing its structural components, examining its surrounding and influencing context and lastly the process of analyzing the functions and functionality of the focal TIS.

4.1 Defining the focal TIS

In this section, I will define the object of analysis, explain the choice between a knowledge field and a product and delimit and define the contextual border of the focal TIS. The delimitation is conducted on the basis of the tailored analytical framework and its guidelines developed in chapter 2. Furthermore, the delineation process is rooted in the four dimensions of technology, value chain, time and geography (Sandén, Jacobsson, Palmblad, & Porsö, 2008) in addition to the TIS's phase of development (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). Furthermore, defining and delimiting the focal TIS poses a challenge for several reasons. For example, the structural components of a TIS is not necessarily permanent or stable (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). Breadth and depth in terms of limiting the study while maintaining relevant context is another challenge. Additionally, there is no "right way" to define and delimit a TIS. This is a consequence of the fact that a TIS is merely an analytical construct as well as the fact that abstract boundaries set in adherence with research questions, aspirations, delineation, scope and context does not necessarily reflect the whole reality of the actual system. However, this process is highly significant due to the fact that boundaries of the focal TIS greatly influences the process and outcome of the empirical research (Markard & Truffer, 2008).

4.1.1 The unit of analysis

It seems reasonable to define the unit of analysis as *fast EV charging stations in Norway* in the time period between their initial emergence sometime around 2011 and up until today. This is because the occurrence of fast EV charging technology and the process of fast EV charging, seemingly only takes place at fast EV charging stations within the context of Norway. Furthermore, fast EV charging stations and the charging service they offer can be considered a product, or rather a group of products, as opposed to a knowledge field. A knowledge field, in terms of for example R&D, technology development- and generation of fast EV charging technology, is arguably of less interest when it comes to the case of increased diffusion and utilization of fast EV charging technology in Norway. This consideration is based on the fact that seemingly little to no fast EV charging technology development- or generation takes place in Norway today (Interview.3) (Interview.7). Furthermore, the focal TIS can be considered to be in a somewhat semi-mature phase where the *production part* of innovation is arguably more dominant than the *innovation part*. The *production part* of innovation in relation to the focal TIS is also arguably the most pertinent part when aspiring to intensify electrification of the Norwegian transportation sector.

4.1.2 Technology

when it comes to charging infrastructure in general, the related technology is arguably easily recognizable and may be defined within the frame of the function of transferring electric energy from for example a power grid to any means of electrically motorized transportation. However, such a definition of the scope of the technology would bring about a vast array of applications. Since charging technology can be applied to various transportation artifacts such as boats, airplanes and road vehicles in numerous ways and locations. These categories would also entail their own separate niches with specific technological and technical requirements and specifications. Therefore, to address the scope of this study and create apt context to answer its research questions, further delimitation and definition of the technological aspect is needed. Starting with an overview of components and their related standards when considering charging infrastructure;

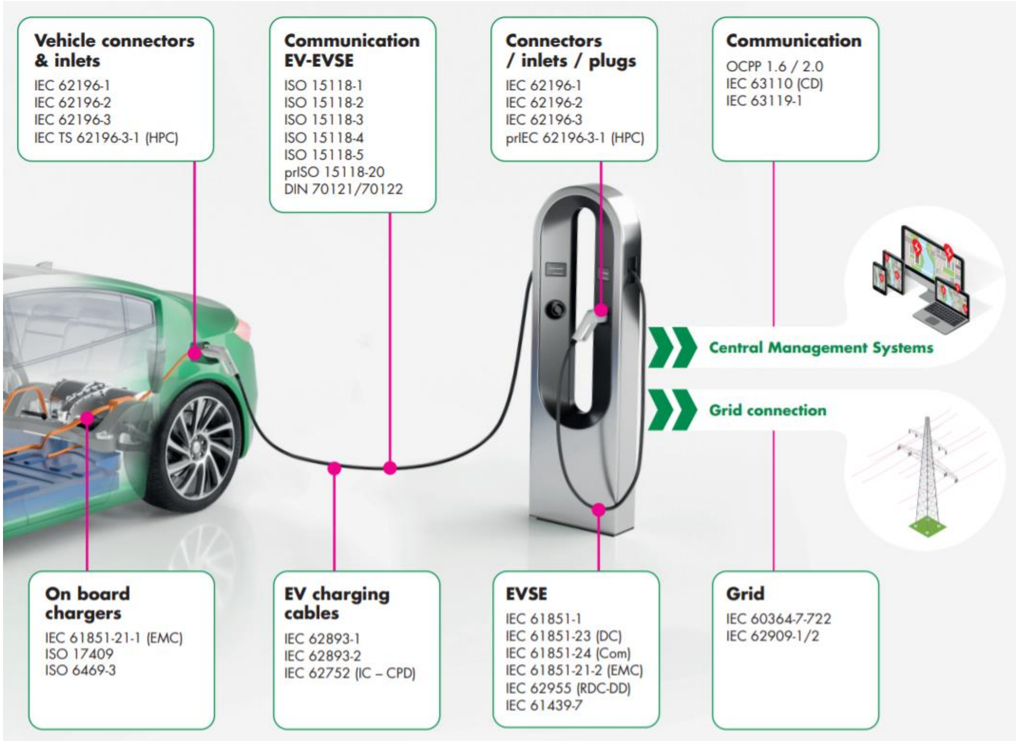


Figure 6) ***Charging infrastructure components and their standards.*** **The figure describes all the standards that the Norwegian Fast EV charging station TIS is subject to when operating within the fast EV charging market** (Dekra, 2020)**. Standards include European- and other international committees such as European Committee for Electrotechnical Standardization (CELNEC), International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC).**

Since fast EV charging stations in Norway are considered the main analytical object of this thesis, it seems appropriate to limit the scope of the focal TIS to fast charging technology applied on this type of physical infrastructure. However, it is important to note that EV charging to a significant extent also is solved by chargers with less than 50 kW output In addition to various alternatives of home- and destination charging.

In terms of categories of charging, *fast charging* is considered for chargers capable of delivering effects between 50 kW – 150 kW (The Norwegian EV association, 2020). *Lightning charging* is considered at effects over 150 kW (ibid). Chargers with effects below 50 kW can be considered either *normal charging* or *semi-fast charging* (The ministry of transport, 2019). *Destination charging* refers to charging at desired destinations such as hotels and shopping centers. *Home charging* refers to charging which is usually conducted at a car owner's house, driveway or housing association. Both home- and destination charging usually occurs at outputs below 50 kW since this type of charging is conducted with alternating current (AC) rather than direct current (DC), which is necessary for fast- and lightning charging. Lower charging output leads to lengthier charging times and charging lines. Of which both can be considered contributing factors related to concerns towards EV usage (The Norwegian EV Association (a), 2019). Therefore, these categories of AC charging seemingly does not address current challenges related to further adoption, diffusion and use of EVs with the same conviction as fast EV charging solutions (The Norwegian EV Association (b), 2019). Although they have been a significant premise for the current state of EV adoption in Norway (Figenbaum & TØI, 2018).

4.1.3 Geographical limitation

In terms of geographical delineation of the focal TIS, it implies a limitation within Norwegian borders. However, the nature of a TIS is seldom actually limited in this fashion (Markard & Truffer, 2008). To be able to adhere to the research questions and create a study that will fit the scope and purpose of this thesis, I have chosen to focus on limiting the conducted research within the borders of Norway where applicable and relevant. Nevertheless, aspects such as global- and influencing factors including international suppliers, knowledge, standards and other examples of context and interplay will be considered to the extent that they contribute to significantly increase understanding of the focal TIS and its functions, while at the same time attempting to limit the size of the size and complexity of this study.

4.1.4 The value chain

When it comes to defining a relevant value chain in order to conceptualize the limits of the focal TIS, a focus on the application context of fast EV chargers has been applied in combination with inclusion of the most influencing aspects and actors of what can be considered to encompass the fast EV charging market in Norway. Consequently, it makes sense to define an industry value chain that describes the process of delivering fast EV charging technology to the operators of the fast EV charging stations and its end-users[22]. To understand the process and actors that contributes to enable the development and operation of fast EV charging stations, a breakdown of the fundamental elements making up the unit of analysis is in order. According to Hempel, fast EV charging stations consist of the following fundamental elements; “fast chargers, access to the power grid and energy, access to roads and real estate as well as a specter of relevant ICT-service providers and processes” (Interview.3).

Based on Porters understanding of a value chain in addition to aforementioned aspects, I have chosen to make a simplified and compiled value chain analysis to briefly outline the categories of involved actors based on their influence and relevant activities that contributes to affect the end-price of a product in addition to deliver the final product of fast EV charging to an end-user (Porter, 1998).

[22] End-users of fast EV charging stations, usually entails consumers in the form of drivers and their privately owned EVs and other small scale road vehicles. In some cases, commercial drivers operating firm-owned vehicles also tend to consume fast EV charging at charging stations (Interview.6, 2020) (Figenbaum & TØI, 2018)

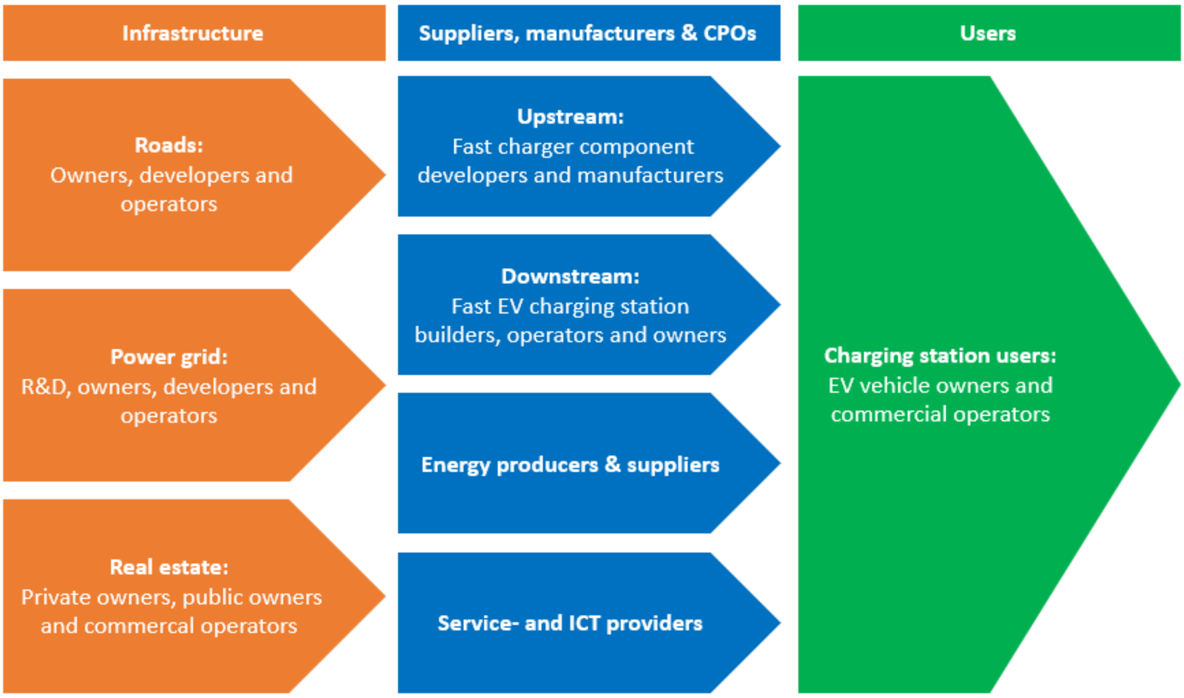


Figure 7) ***The value chain of fast EV charging stations in Norway*****. The figure briefly describes compiled categories of actors and their activities which contributes to the end price of fast EV charging in addition to make the product of fast charging available to end-users. The model is based on Porter's understanding of the concept of industry value chains with several simplifications and adaptations to establish conceptual limitations of the focal TIS** (Porter, 1998)**.**

In the case of fast EV charging in Norway, downstream actors are mostly comprised of CPOs and their end-users. Several of the actors within the value chain, including some of the CPOs, also operates outside of Norway. However, it is their impact related to the focal TIS through their contribution towards diffusion and utilization of fast EV charging technology in Norway that is of main interest. Therefore, various forms of operations taking place outside of Norway have received minimal focus.

When it comes to upstream- and manufacturing actors, we find that they share quite a few attributes. These two aspects of the value chain are mostly comprised of R&D, development and manufacturing of technical components in addition to various activities related to knowledge and human resources. Furthermore, we find that probably none of these actors has operations besides sales within Norway (Interview.7) (Interview.3) (interview.1). As stated by Lima: "There is no producers or developers of HW in Norway related to fast EV charging to my knowledge." (Interview.7). It is therefore challenging to limit this part of the value chain within Norway. However, only the most pertinent actors and factors within this aspect shall be examined, since they only serve to increase understanding of some of the functions related to the focal TIS, and not the majority of them.

Physical infrastructure such as roads, real estate and the power grid are of course highly relevant for the value chain of fast EV chargers. However, these types of actors and critical infrastructure have more of an indirect rather than a direct influence on the value chain Therefore, they will be examined at a later stage during this analysis.

Service providers, software developers and energy suppliers also embody an indirect and direct influence on the value chain. Since they provide various IT- and payment solutions as well as a significant part of delivering fast EV charging to consumers via providing energy in the form of electricity.

4.2 Structural components

In this section of the analysis, application of the contextual limits of the focal TIS in terms of focusing on nationally relevant and located actors have been applied to the extent that it is possible without leaving out significant empirical findings and context. Consequently, this empirical presentation of structural components is not exhaustive in terms of including all of the actors whom interacts with the focal TIS. Rather the most relevant and influential ones in terms of contributing to explain and understand the functions and functionality of the focal TIS, its surrounding and influencing context as well as serving the scope, research questions and aspirations of this study.

4.2.1 Actors: Firms

When considering the most relevant types of actors whom can be considered components of the focal TIS through various forms of interplay, several unique categories of firms emerge. The most significant ones include CPOs, upstream suppliers and manufacturers, utility companies, car companies and *energy station retailers*[23].

The CPOs: This type of firms refers to actors within the focal TIS whom engages in installation, maintenance, support and operations related to making fast EV charging stations available throughout Norway. The CPOs whom operates within the fast EV charging segment seems to be primarily 3CPOs. Consequently, technology generation- and development has not been pointed out as a core activity for these types of firms within the Norwegian market. This

[23] Energy station retailers refers to what has commonly been understood as traditional fuel retailers, now offering several forms of fuel. Traditionally, fuel stations served as infrastructure and energy supply for ICEVs. Modern fuel stations serves as energy stations for several forms of alternative fuels such as electricity and biofuel as well as traditional fossil-based forms of fuel.

is due to the fact that fast EV charging technology typically is developed, manufactured and exported by international suppliers[24] (Interview.7) (Interview.3) (interview.1) (Interview.2).

There are mainly 10 CPOs operating in the Norwegian fast EV charging market. Of these 10, Fortum Charge & Drive together with Grønn Kontakt represents the majority of the fast EV charging market (Interview.3) (Interview.2) with over 200 lightning chargers and 1200 fast chargers across 600 charging stations between them (The Norwegian EV association, 2020). Additionally, various Norwegian and international utility companies such as Agder Energi, BKK, lyse and E.ON is diversifying their portfolios with fast EV charging products. The energy station retailer Circle K and car company venture Ionity has also recently entered the fast EV charging market together with some recently established Norwegian start-ups including Supercharge and Koble.

Operators	Fast charging stations	Lightning chargers	Fast chargers
Fortum	320	100	750
Grønn Kontakt	250	121	477
BKK	90	200	210
Tesla	61	802	
Circle K	32	62	84
Ionity	15	72	
Lyse	11	12	58
Supercharge	7	22	16
Kople	5	18	22
E.ON	2	3	6

Table 1) *CPO overview for the Norwegian market*. The table shows an overview over the 10 fast EV charging station operators within Norway, their number of fast charging stations as well as number of fast- and lightning chargers and charging points (The Norwegian EV association, 2020)**.**

Fortum owns and operates 320 fast charging stations in Norway and entered the market at a considerably early stage in 2011 (The Norwegian EV association, 2020) (Interview.3). This CPO also operates within the home- and destination charging market. Fortum has stated clear ambitions to quadruple the development of publicly available charging stations in Norway on their own during 2019 – 2020 (Fortum, 2020). To increase resources and capacity, Fortum sold a majority share of its EV charging business to Infracapital in 2020. In addition to their charging infrastructure

[24] Note that this is not necessarily true for other markets and segments and that this research is not completely exhaustive in terms of investigating all the CPOs whom participates in the Norwegian market. Rather an in-depth qualitative examination of the major and dominant actors considering the context of the focal TIS. Zaptec is for example a Norwegian CPO operating within the home- and destination charging segment whom develops, designs and manufactures their own AC charging technology (Interview.7) (Zaptec, 2020).

business, Fortum engages in power supply, cooling- and heating solutions as well as smart and digital ICT services such as Charge&Drive, the leading digital mobile service for public EV charging in the Nordics.

grønn kontakt Grønn Kontakt is a National EV charging infrastructure operator with 250 fast EV charging stations throughout Norway (The Norwegian EV association, 2020). Grønn Kontakt also operates within the home- and destination charging segment and initially entered the market at an early stage as a project within Agder Energi in 2011 (Interview.2). Furthermore, Grønn Kontakt offers their own mobile application and a charging map. The company is owned by Statkraft (55 %) and Agder Energi (40 %). Both Statkraft and Agder Energi is owned by the Norwegian government (Grønn Kontakt, 2020).

BKK BKK, a Norwegian state-owned utility company, Operates 90 fast EV charging stations throughout Norway (The Norwegian EV association, 2020). In terms of charging services and products, BKK operates within home- and destination charging, fast EV charging in addition to charging infrastructure for sea transportation. Furthermore, this CPO also engages in ICT related activities by developing and operating an EV charging mobile application as well as a charging map. This CPO differs from some of the other CPOs by collaborating exclusively with ABB as a charging technology supplier. As opposed to a rather pragmatic relationship with suppliers which is more commonly applied in the market (Interview.3) (Interview.2).

TESLA Tesla Operates 61 charging stations and a staggering 800 lightning chargers which encompasses over 50 % of all lightning chargers in Norway (The Norwegian EV association, 2020)**.** However, this operator is primarily a technology developer and provider. In short, this means that that the Tesla charging infrastructure is only available for Tesla cars, which leaves the question as to whether their charging infrastructure should be considered publicly available or not. Furthermore, Tesla's motivation for developing and operating charging infrastructure can be considered to be more commercially oriented to increase the sale and adoption of their cars, not necessarily all EVs. Either way, tesla vehicles makes up a significant amount of the electrified Norwegian car park as well as the majority of lightning chargers. Consequently, Tesla and their charging business will be considered to some extent within this study as an outlier.

CIRCLE K Circe K Is a new entrant that operates 32 fast EV charging stations throughout Norway (The Norwegian EV association, 2020). This CPO operates within the home- and destination charging segment in addition to fast EV charging (Circle K, 2020). Furthermore, Circle K has global ambitions for their fast EV charging business and is unique in their motivations for marked entry as a former global gas station retailer. Now a global retailer of energy stations whom aspires to maintain and increase their relevance in a changing marketplace (interview.1). In terms of ICT services and capabilities, Circle K also offer a charging map as well as their own mobile application (Circle K, 2020).

Ionity Is a European joint venture between German car producers; The Volkswagen Group, Audi, Porsche, BMW, Mercedes and Ford. The high powered EV charging infrastructure company currently operates 265 lightning EV charging stations throughout Europe (Ionity, 2020), where about 15 of these are located in Norway (The Norwegian EV association, 2020). Founded late in 2017 and with only a recent emergence within the Norwegian market, the actor can be considered a new entrant.

Lyse is a Norwegian utility company similar to BKK. Through a collaboration with BKK, this utility-based CPO operates 11 fast charging stations throughout the south-western part of Norway (The Norwegian EV association, 2020). Lyse is also operating within the home- and destination charging segment (Lyse, 2020) and is also a state-owned enterprise (SOE).

Supercharge is national new entrant that operates 7 fast charging stations throughout Norway (The Norwegian EV association, 2020). In addition to fast EV charging stations, Supercharge delivers solutions within construction sites, home charging, destination charging, fuel stations and parking lots (Supercharge, 2020).

Kople Is a newly established Norwegian CPO owned by the state-owned utility company Ringerikskraft. Kople operates 5 fast charging stations in the southern part of Norway (The Norwegian EV association, 2020). This firm also delivers solutions within workspaces and parking spaces as well as home- and destination charging (Koble, 2020).

E.ON is a German utility company whom recently also entered the fast EV charging market. Even though this CPO is a new entrant to the Norwegian market it has extensive charging infrastructure operations in Denmark and Sweden (E.ON, 2020). In Norway, E.ON has established 2 fast EV charging stations so far in 2020 (The Norwegian EV association, 2020). Besides fast EV charging stations, E.ON also offers home charging in Norway (E.ON, 2020).

Upstream suppliers and manufacturers: This type of firms embodies the role of technology generators and developers as well as suppliers of fast EV charging technology towards the Norwegian market. Initially, incumbent technology developing giants such as ABB, FAC and Tritium has served as fast EV charging technology providers (Interview.3) (Interview.2). Although as of late, new entrants and pivoting companies like Alpitronic are entering this part of the charging industry (ibid).

Utility companies: As can be deduced from their role related to CPOs, utility firms are both a premise- and resource provider in addition to acting as a stakeholder in terms of interactions with the focal TIS. Several of the Norwegian state-owned utility companies holds various stakes in many of the CPOs. Meaning that they represent an important source of both political influence, knowledge as well as financial- and human resources. Others have a direct connection to the focal TIS by engaging in the fast EV charging market, such as Lyse and BKK. Furthermore, Grønn Kontakt was initially established as a project within the power grid division of Agder Energy and was later founded as its own entity and recently sold off (Interview.2). Additionally, the pace and direction of electrification of Norway can have a significant impact on the role and future outlook of utility companies (ibid). Hence, they can be considered stakeholders in relation to the ongoing green transition of Norwegian transportation. Furthermore, this type of firms serves as premise providers for several reasons. The most prevalent ones being their role as energy producers, energy providers and power grid operators. CPOs are also customers of the utility companies in terms of purchasing energy and interacting with the power grid (Interview.3). Lastly, as we shall see during the function analysis part of this chapter, several of the utility companies participate in R&D projects related to EV- and fast EV charging development.

Energy stations: This type of actors are both occurring as a location provider for CPOs as well as taking on the role as CPOs themselves (interview.1). As mentioned, Circle K is one of several new entrants in the Norwegian charging market. Other energy station brands such as Shell and Esso have chosen other approaches and business models when addressing the emergence of EVs and EV charging by for example initiating collaborations and renting out parts of their commercial real estate (ibid) (Interview.5). The significance of this type of firms springs from their already existing presence throughout Norway together with strategically sound placements related to the Norwegian *traffic pattern*[25] (Drivkraft Norge, 2020). Estimations suggests that there was over 1.700 energy stations throughout Norway in 2019 (ibid).

Car companies: Developers and manufacturers of EVs and other vehicles plays a significant role in relation to the focal TIS through various forms of interplay. Technological improvements, increased performance and efficiencies, price reductions and other product related characteristics of EVs affects users' behaviors and experiences, which in turn may affect user-patterns (Figenbaum & TØI, 2018). *Range anxiety*[26] is for example still very much a real concern for current consumers of EVs (The Norwegian EV Association (a), 2019). A concern which could theoretically be reduced in part by increased range on EVs. These firms have also expressed and demonstrated their interest in taking part in the global electrification transition within transportation by claiming a role within the EV charging infrastructure market. This role is not solely related to investment and profitability (e.g. ventures like Ionity), but also related to ICT and seizing control over the dialog and relationship between the car and the car-owners (Interview.3) (Interview.2). As stated by Hempel; "The car producers want priorities on their charging certificates and payment solutions" (Interview.3). Furthermore, these firms are striving to venture into the electrification market (ibid). ICT and ICT-capabilities are becoming an increasingly relevant factor within modern vehicles through for example their interactions with its driver and surroundings. Making these firms a relevant influence as to the future outlook of consumption of small scale vehicles like EVs, charging infrastructure and the interface that facilitates the interaction between them (Interview.2).

4.2.2 Actors: Associations and interest groups

When investigating actors within the role of associations and interest groups whom interacts and influences the focal TIS, the immaturity of the system becomes evident. Few purely national or topically focused actors within this category exists or has been found during the analysis. Charging infrastructure often comes second to EVs as a subtheme when included as either for example a topic or a business area. For example, Norway's Automobile Association (NAF) and The Norwegian EV Association primarily serve car owners and therefore have an indirect, yet clearly expressed, interest in fast EV charging stations. Therefore, only a few

[25] Own translation of "Trafikkbilde", refering to the amount and nature of traffic within a given area (Drivkraft Norge, 2020)
[26] Range anxiey refers to EV driver's concerns related to the range of an EV (Grøndahl, 2020). A concern that may lead to for example, choosing to use an ICEV for conducting transportation where an EV could be used, or even choosing to buy an ICEV over an EV (The Norwegian EV Association, 2019).

significant national actors was found within this category. Furthermore, since more topically focused associations and interest groups exists, although most often in the form of international actors, I have included a few honorable mentions of these as well.

The most influential and relevant national associations and interest groups are mostly comprised of a few prominent associations such as The Norwegian EV association and Drivkraft Norge. These actors typically engage in furthering their membership's interests by practicing political influence, coordinating political efforts and engaging in knowledge related activities and networks (Interview.5) (Interview.4).

The Norwegian EV Association is a Norwegian EV-owner interest organization founded in 2000. The association's main goal is to promote adoption and widespread use of EVs fueled by green energy. Through representing Norwegian EV owners, in addition to collaborating with The Norwegian Government and the car industry, The Norwegian EV associations strives to promote Norway as a best case for EV policy internationally (The Norwegian EV Association, 2020). The association is a non-profit organization and is also affiliated with several other international associations such as the European Association for Electromobility (AVERE) and the World Electric Vehicle Association (WEVA) (ibid).

Drivkraft Norge is an association representing firms whom sell liquid fuel and energy (Drivkraft Norge, 2020). Although the association historically has focused on the oil industry, the green transition taking place in Norway is currently disruption this incumbent industry, making for example engaging in the charging market potentially lucrative or even necessary (Interview.5) (interview.1). This has led the oil industry and associations such as Drivkraft Norge to increasingly engage with the focal TIS. Drivkraft Norge's interplay with the focal TIS entails for example political- and knowledge related activities such as interpreting political statements and documents in addition to represent their membership organizations in political settings (ibid). Gotaas summaries their role in relation to fast EV charging as follows: "We are standing right in the middle of the political challenges related to governmental entities such as NVE, the municipalities and private actors such as associations and CPOs" (ibid).

Other relevant associations and interest organizations are for example Virke (interview.1), The Norwegian Association of Local and Regional Authorities (KS) (Interview.6) and the technology orientated news and media platform Teknisk Ukeblad (TU). TU strives to highlight the importance of technology and how the phenom can be used to solve current and future challenges (TU, 2013). They influences the Norwegian charging industry through its publishing activities as well as collaborative initiatives. For example, hosting events such as the Nordic EV Summit. Virke, The Federation of Norwegian Enterprise, is an employers' organization with more than 24.000 member companies. Its relevance and interplay with the focal TIS arises as a consequence of its political efforts, capabilities and activities including political initiatives related to fast EV charging (Interview.5) . Lastly, KS represents public employers and embodies a significant role in relation to the focal TIS by offering knowledge, guidance and advice for public actors such as municipalities (ibid) (Interview.6). Lastly, Footprint is a knowledge-based consulting firm whom has been engaged within political efforts related to the focal TIS such as collaborations related to political hearings (interview.1).

Examples of international associations and interest groups are AVERE, whom influences the focal TIS through contributing to the discussion related to EU policies, acting as a forum of knowledge as well as an international network through hosting global events such as the Electric Vehicles Symposium (EVS) together with WEVA (AVERE, 2020). WEVA is a non-profit organization whom aspires to promote research, knowledge, development and deployment of EVs globally (WEVA, 2020). Other mentionable international associations and interest groups are for example the European Automobile Manufacturers Association (ACEA), the European Federation for Transport and Environment (T&E) and Dekra. Dekra is a German company that engages in R&D, advisory activities related to standards, product testing, inspection and certification of, among other technologies, electrified vehicles and charging infrastructure (Dekra, 2020). Dekra is also an avid participant, speaker and partner in various activities and networks such as international forums, summits and research projects.

4.2.3 Actors: Universities and research institutions

Through literary reviews and analysis, semi-structured expert interviews combined with investigating formal networks and research institutions, 2 prominent Norwegian research projects where found in relation to the focal TIS. Namely the ELAN project and FuChar. By examining these projects, an outline of actors related to research, knowledge development and knowledge diffusion with reasonably relevant and influencing interaction with the focal TIS has been made.

The ELAN-project is led by The Institute of Transport Economics (TØI), a Norwegian, independent research institution which aspires to deliver applied research within issues and challenges related to transportation. Furthermore, this research institution promotes application of their research by functioning as an advisor for the government, relevant industries and the public in general (TØI, 2020). TØI receives their annual base funding from the Norwegian Research Council. The institute mainly conducts research on behalf of Norwegian authorities and organizations such as The Norwegian Research Council and The Ministry of Transportation (ibid). Often in collaboration with various other public or private actors. Additionally, they take on projects from the European Commission, public authorities, various international organizations and private actors (ibid). In terms of relevant actors related to research and knowledge development, some of the listed participants of the ELAN project include the Vienna University of Technology, the Norwegian EV Association, NAF, The Norwegian Public Roads Administration (SVV), The Oslo Municipality, various car producers, associations and Fortum Charge & Drive (ibid).

Another significant and influential research institution related to the focal TIS is Sintef, project lead on the second significant research project in relation to the focal TIS, FuChar. Sintef is an independent, Norwegian research institute focusing on, among other fields, technology as well as natural- and social sciences. As a diverse and multidisciplinary organization, the Sintef Community both acts as a contract R&D provider for public and private actors as well as applying research through for example commercialization of research results by the means of licensing or establishment and investments related to spin-offs (Sintef, 2020). Furthermore, Sintef has firm relations with Norwegian universities such as the University of Oslo (UiO) and the Norwegian University of Science and Technology (NTNU) (ibid). The FuChar-project is categorized as a competence building project and is financed by The Research Council of Norway. In terms of relevant partners, the majority of distribution grid owners and operators in Norway are included. Among others, Hafslund Nett, Agder Energi Nett, Haugaland Kraft Nett, Istad Nett and Skagerak Nett (ibid). Other partners include institutions such as SVV and The Norwegian Water Resources and Energy Directorate (NVE) as well as The Norwegian EV association, NTNU and the European CPO Ionity (ibid).

4.2.4 Networks

Assessing networks, both formal and informal, can be a challenge for several reasons. Since the focal TIS has seemingly only recently emerged and therefore is rather immature, the forming of networks and institutional alignment is probably weak and unexplicit (Markard & Truffer, 2008), making the examination of this structural component and its interplay with the focal TIS an empirical challenge (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008).

Furthermore, networks are often informal and therefore difficult to detect or document without interviewing or discussing with the majority of actors involved. This is because communication and interaction within such networks most often is not measured or documented. For example, communications between employees within different firms, institutions and various organizations within the focal TIS. Mapping this structural component has therefore required various research methods and sources as well as a little bit of informed guesswork.

Formal networks: Networks such as the research collaborations ELAN- and FuChar-projects led by TØI and Sintef are good examples of formal networks related to the focal TIS (Interview.4). Other examples are political hearings related to laws and regulations governing the Norwegian fast EV charging market (Interview.6) (Interview.5) (Interview.4) (Interview.2) (interview.1). As stated by Gotaas; "Hearings at NVE are very important. All actors were present during the hearing this late summer. About 130 actors." (Interview.5). At these hearings, institutional actors such as NVE invite subjected and relevant actors to revise and discuss development in for example modernizations of tariffs and classifications (Interview.6) (Interview.5) (Interview.4) (Interview.2) (interview.1). In this aspect, associations such as The Norwegian EV association, KS and Drivkraft Norge serves as formal networks. They do so by hosting panels and discussions related to formulating political actions (Interview.5) (Interview.4). These actions are often executed by these associations and interest groups on behalf of CPOs and other private- and public actors by expressing their collective interests through for example political processes such as hearings (Interview.6) (Interview.5) (Interview.4) (interview.1) (NVE, 2020). Additionally, Footprint was mentioned as a proficient political network through for example; "Hosting collaborations between CPOs by executing lobbying activities towards NVE, The Storting and parliamentary groups." (interview.1).

Other examples of formal networks are national and international forums, summits and events being conducted annually. The relevance of these networks can be outlined by examining participants and event organizers related to them.

Institutional actors	CPOs	Media and research	Various actors; utilities, car companies, suppliers etc..
Agency for Urban Environment	BKK	Aften Posten	ABB
Bergen Municipality	Circle K	TU	AVERE
Enova	Fortum	TØI	DNV GL
Halden Municipality	Grønn Kontakt	Center for International Climate Research	Drivkraft Norge
Innovation Norway	Ionity	Nordic Energy Research	Jaguar Land Rover
The Norwegian Climate Agency	Lyse	NMBU	Fjordkraft AS
Trondheim Municipality	Supercharge	NRK	NAF
Østfold Municipality	E.ON	NTNU	Nissan
SVV		Elbil24	BMW
		TEK.no	Hafslund
			Renault
			Schneider Electric
			Toyota
			Skagerak Energi AS
			Statkraft AS
			The Norwegian Automobile Importers' Association
			The Norwegian EV Association

Table 2) *Examples of relevant actors participating in the Nordic EV summit 2019*. As can be observed, actors from all structural components within the focal TIS was present at this summit in 2019 (Nordic EV summit, 2020)**.**

Within this type of networks, aforementioned associations, interest groups, car companies, utility companies, various media actors, technology developers and suppliers and universities and research institutions connected to the focal TIS interacts by serving as either event organizers, sponsors, speakers or participants (Nordic EV summit, 2020). However, few of the events and forums found during the analysis are particularly concentrated on or within the Norwegian market. Furthermore, when it comes to the topics and themes of most of these types of formal networks, fast EV charging infrastructure, or even charging infrastructure in general, is most often the byline and not the headline. For example, one of the major transport electrification summits in Europe is The Nordic EV Summit. Furthermore, we find The Electric Vehicles Symposium organized by AVERE. We also have The European EV Charging Summit organized by Active Communications International (ACI) and The EV Charging Infrastructure Summit by the IQ Hub.

Informal networks: This type of networks are rather challenging to document. However, through conducting semi-structured interviews, informal networks connected to the focal TIS can be described as for example, associations and interest groups hosting various knowledge development- and diffusion activities on behalf of their members. Including communication and meeting activities related to political efforts such as various forms of collaborations as well as developing inputs at hearings regarding development within for example laws and regulations (Interview.5) (Interview.4) (interview.1). Other examples can be communication between employees or groups of employees of various actors within the focal TIS.

4.2.5 Institutions

When considering institutions, this section will more or less be limited to directly interacting and influencing actors whom can be categorized as institutional in relation to the focal TIS. This is due to the fact that the fast EV charging market and its CPOs are influenced by multitude of both international and national laws, regulations and standards as well as other institutional factors such as cultures, norms, routines and knowledge (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). Furthermore, Institutions play an essential role for establishing and maintaining functional industries and markets. Therefore, their alignment in terms of soft infrastructure needs of new and emerging technologies is critical (Bergek, 2002). Additionally, these types of actors often contribute to mediating conflicts, coordinating knowledge as well as establishing incentive systems for various actors (Lundvall, 2010).

Examining all of the relevant institutional actors in-depth is not feasible within the format and scope of this study. Furthermore, the number of *significantly relevant institutional actors* is certainly smaller than the sum of *all the influencing ones*. Additionally, the *significantly relevant institutional actors* arguably represents the majority of influential capital affecting the focal TIS. An in-depth examination of these specific actors should thus lead to a substantial increase in understanding of the focal TIS's functions and dynamics related to its interplay with institutions. I have also chosen to simplify and narrow down this structural component by breaking it down into national- and international institutional actors. Since the characteristic of geographical location and affiliation tends to represent vast differences in origin, mandate and aspirations within this type of structural components.

National institutional actors: The Norwegian Government governs and manages several of the relevant institutions that makes up what can be considered to be the Norwegian political- and institutional context surrounding the focal TIS. The Norwegian Government exercises its influence through developing new laws, practicing policies and developing and executing the national budget (Regjeringen, 2019). Subject to The Norwegian Government are, among other institutional actors; ministries, directorates, municipalities and various agencies. Other examples of relevant institutional actors are Enova and Innovation Norway which serves in part as financial institutions in relation to the focal TIS. Lastly, The Norwegian Electrotechnical Committee (NEK), an independent and neutral standardization organization with focus on electrotechnical technology, is another nationally occurring institutional actor related to standards.

The ministries affect the focal TIS in several aspects. The most significant ministry is arguably The Ministry of Transportation. However, The Ministry of Petroleum and Energy, The Ministry of Foreign Affairs, The Ministry of Local Government and Modernization and The Ministry of Justice and Public Security all embodies substantial surrounding influence and context regarding the focal TIS.

The Ministry of Transportation is significant through its responsibilities related to transportation and infrastructure. It executes its influence through developing policies, laws, and regulations related to transportation. Often influenced and based on EU policies, laws, regulations, standards and directives (The Norwegian EV Association (b), 2019). Furthermore, it manages assets and infrastructure such as roads, railroads and ferry docks through, among other agencies, SVV whom are responsible for the maintenance, development and operations of the Norwegian road network. The Ministry of Transportation also encompasses several Norwegian transportation related SOEs as well as responsibility for developing and executing current and future NTPs (Regjeringen, 2020).

The latter ministries are to a smaller degree directly influencing the focal TIS. For example, The Ministry of Foreign Affairs manages, among other responsibilities, international climate concerns and commitments. It also strives to hold Norway accountable to such commitments and thus greatly influences the surrounding political and institutional context of the focal TIS (Interview.5), since; “International commitments are essential to drive climate efforts in Norway” (Interview.3). Furthermore, The Ministry of Petroleum and Energy’s mandate entails a coordinated national energy policy, including, among other aspects, the management of NVE (The Norwegian Government, 2020). NVE is a significant premise provider in regard to constructing and operating fast EV charging stations through such station’s interplay with the power grid via for example energy tariffs (Interview.4) (Interview.3) (Interview.2) (interview.1). Additionally, The Ministry of Local Government and Modernization’s mandate includes, among other responsibilities, managing the planning and building act. An act which directly dictates the terms of constructing charging infrastructure in Norway (Ministry of Local Government and Modernisation, 2020). Lastly, The Ministry of Justice and Public Security manages, among other responsibilities, The Norwegian Directorate for Civil Protection (DSB). DSB maintains an overview of various risks and vulnerabilities within the

Norwegian society in general. Including considerations regarding operations and use of fast EV charging technology (DSB, 2020) (Interview.5).

In terms of agencies and directorates, the Norwegian Environment Agency offers financial aid and public funding for analysis, development and construction related to fast EV charging stations through their aid scheme “Klimasats”. Directed towards municipalities and county municipalities. The agency works towards a clean environment by the means of reducing GHG emissions and pollution in addition to manage Norwegian nature (The Norwegian Environment Agency, 2020). The Municipality of Oslo’s Climate Agency is another institutional actor whom are designated to engage with climate efforts in line with Oslo’s climate strategy through various measures (The Municipality Oslo's Climate Agency, 2019).

Further, the municipalities throughout Norway plays a vital role in relation to diffusion and utilization of fast EV charging technology (Interview.6) (Interview.5). They practice their influence towards the focal TIS through potential roles such as customers, financial supporters and landlords. Municipalities can also greatly influence the surrounding context of a charging station by for example regulating local law and regulations related to business and transportation to for example favor electric mobility (Interview.6). Furthermore, Kristiansen states that municipalities can be instrumental to support market development in commercially challenged areas; “home nursing are examples of governmental services that can be electrified and contribute to drive market development by engaging local municipalities” (ibid). This institutional actor is also in many ways made responsible for enacting climate goals initiated by The Norwegian Government, and is therefore highly concerned with addressing local climate goals and initiatives (ibid) (The Norwegian Goverment, 2017).

Enova is a significantly influential financial institution related to the focal TIS through its institutional role and mandate (Interview.3) (Interview.2). Including managing public resources such as capital pegged for electrification of the Norwegian economy. In short Enova’s mission is to promote environmentally friendly production and consumption of energy (Enova, 2020). One of the major tools this institution applies to support the development of charging infrastructure in Norway, is financial incentives in the form of public funding. Enova states that;

> The goal of the incentives is to increase the attractiveness of EVs by the means of ensuring a basic supply of fast chargers in areas where public funding is still a necessity. Furthermore, we are going to contribute to a sustainable market for charging

infrastructure, so that development and construction of fast- and lightning chargers can be market-driven in the long run (ibid).

Historically, Enova has offered to cover up to 40 % of the cost of developing fast EV charging stations in 287 municipalities, given a few prerequisites (Enova, 2017). Furthermore, Enova has been instrumental for the state of current development of the fast EV charging network currently existing in Norway today (Interview.6) (Interview.4) (Interview.3) (Interview.2). In addition to Enova, Innovation Norway is a SOE whom also provides financial resources within the focal TIS by operating as a state-owned development bank (Innovation Norway, 2020).

The Research Council of Norway is an institution that manages financial capital on behalf of the Norwegian government within state funded research. In 2019, the council invested 11 billion NOK towards research related to innovation. In short, the council aspires to promote high quality research which may contribute to generate knowledge in Norwegian priority areas to meet challenges within the Norwegian society and business sectors (The Research Council of Norway, 2020). A highly relevant program under the umbrella of the Research Council of Norway is ENERGIX. The program finances research and innovation related to sustainable development of the energy system, including industry, transportation and construction (The Research council of Norway, 2020)

Both the charging- and the car industry is dominated by national and international soft infrastructure such as laws, standards, directives and norms. Much of the soft infrastructure governing and influencing the Norwegian EV- and charging infrastructure industry and market, are mostly based directly or indirectly on international standards from institutions such as the EU, CENELEC and IEC. See figure 6 in section 4.1.2 for an overview of standards related to components within an EV charging station. However, in Norway, NEK is in charge of Norwegian standardization efforts through development and approval of national electrotechnical norms and standards. NEK is a member organization with over 100 standardization committees and 600 panel experts (NEK, 2020). Furthermore, NEK also represents Norway within the European standardization organizations CENELEC and IEC (ibid). In short, NEK aspires to ensure that Norwegian electrotechnical norms and standards accommodates the Norwegian society's needs for security, functions and environmental aspects within technical specifications. In terms of national and international regulations, these are most often managed by various executive bodies within the Norwegian government.

International institutional actors : Significantly influential and interacting international institutions that affects the focal TIS's culture, norms, regulations and laws can generally be narrowed down to The EU, in addition various standardization institutions such as ISO, IEC and CELNEC (Interview.5) (Interview.4) (Interview.3). Several other international institutions are potentially influencing the focal TIS in various degrees, either directly or indirectly. However, The EU stands out as the most pertinent one when it comes to explaining functions, functionality and the surrounding and influencing context of the focal TIS. As stated by Gotaas; "The EU is very central for alignment in Norway as well as governmental support framework and regulation." (Interview.5).

The EU is connected to the focal TIS through being an advocate of addressing climate change via for example increased generation, development, adoption, diffusion and utilization of technologies such as EVs and fast EV charging. It practices this advocacy through its initiatives by for example prioritizing electromobility in its Community Research Programme as well as funding the cause through several measures including The Green Emotion (EU, 2020). Other EU initiatives include research programmes like Horizon 2020. The biggest research and innovation programme ever made with about 80 billion EUR made available for funding within the period of 2014-2020 (EU, 2020). Additionally, The EU interacts with the focal TIS by directly funding actors such as Ionity through the Connecting Europe Facility for Transport programme (CEF-T), EU's funding instrument to contribute to realize European transport infrastructure policy (EU, 2020). In 2019, the programme contributed 39.1 million EUR to Ionity's EUROP-E project. The Ionity managed EUROP-E project is aiming to build 340 Fast EV charging stations throughout 13 EU member states with an average of 6 charging points per station. Each charging point will have a capacity up to 350 kW (EUROP-E, 2020).

Besides interacting with the focal TIS in various ways through a wide array of European programmes and initiatives, The EU practices additional influence by means of European standards, directives and regulations related to transportation- and energy sectors, EVs and EV charging. For example, The EU was responsible for developing the dominant CCS fast EV charging-contact standard (Interview.3). In the EU region, Directive 2014/94/EU gives guidelines for both normal- and fast EV charging infrastructure by demanding that normal EV charging using AC should be equipped with a type-2-contact and fast charging based on DC with effects above 50 kW should be equipped with a CCS-contact (The Norwegian EV Association (b), 2019). The EU also serves as a source for soft infrastructure within Norway.

For example, in 2019 The Norwegian Ministry of Transportation developed a draft for new laws and regulations matching the requirements of the 2014/94/EU-directive.

4.3 Surrounding and influencing context

In this section, Bergek's conceptualization of contextual structures and interaction dynamics in combination with the notion of the socio-technological landscape will be addressed in order to conceptualize and analyze the surrounding and influencing context and dynamics of the focal TIS.

4.3.1 Landscape factors

landscape factors contribute to explain the surrounding and influencing context of a TIS by describing factors such as largely autonomous and independent background variables that can affect transition processes. However, such factors are not necessarily affected by transitional processes (Kemp & Rotmans, 2005). Landscape factors that affect the focal TIS Includes international aspects such as economic growth, prices on various resources, pandemics and other crisis and cultural- and normative values (Geels, 2002). The most prominent international factors being a trend within change of values and norms related to the global climate in addition to the ongoing covid pandemic. However, relevant national landscape factors also exists within the geography of Norway. However, most factors that can be considered national landscape factors highly correlates with the geographical context related to the focal TIS. To simplify the analysis of this aspect, national landscape factors will therefore be addressed together with the geographical context in section 4.3.4.

In terms of global landscape factors, the recent and ongoing covid pandemic has led to several dramatic measures such as travel restrictions affecting the way we can- and choose to travel. Furthermore, these restrictions also greatly influenced Norwegian citizen's vacation alternatives, leading to a great deal of Norwegians spending their vacation within the borders of Norway. Elbilisten 2020 has found that this turn of events has significantly increased EV-usage in Norway since March 2020. Especially during the Norwegian summer vacation. A phenom often referred to as; "A stress test for the Norwegian charging infrastructure network" (The Norwegian EV Association, 2020). In short, 43 % EV car owners stated that they used their EV during vacation trips with 1 night stay over or more, compared to 35 % in 2019 (The Norwegian EV Association, 2020). Additionally, 48 % of respondents stated that they intended to use an EV while vacating in 2020 and 47 % stated that trips with an EV replaced planned trips using an airplane this year (ibid), greatly affecting user- and traffic-patterns throughout Norway in 2020.

In terms of the global economy, the Pandemic is estimated to trigger an economic recession with a contraction of 4,9 % (Forbes, 2020). A set-back which has triggered ambitious EU measures including a pledge that the pandemic will not harm European climate goals. Additionally, The EU argues that it can raise 150 billion USD to fund clean-tech and RETs throughout Europe by means of its *green recovery package* (The Guardian, 2020). Efforts like EU's green recovery package in combination with an overarching change of perception related to climate and climate change, speaks to a significant development of alterations within norms and values related to the climate in general. As stated by J.P. Morgan;

> It seems likely that 2020 will see an increased focus on sustainability within the investment community. Savers are increasingly interested in how their money is being put to work, while numerous sustainability issues are high on policymakers' agendas (2019, s. 9).

The alterations in norms and values are arguably affecting how we prioritize, invest and consume. Consequently, global investments in RETs rose by 2 % in 2017 with a positive outlook moving forward (Investopedia, 2019). Nevertheless, outlook for public support related to green industries currently greatly differs from region to region. Europe is seemingly the best place to be with its explicit goals and efforts. Meanwhile, Trump has chosen to reduce green economy protections and China has seemingly not yet taken a stance towards whether or not they will stand behind the green industry or not (Forbes, 2020). In terms of national concerns and alterations in values and norms, 25 % of respondents of Elbilisten 2019 stated that climate concerns was their main reason for buying an EV (The Norwegian EV Association (a), 2019).

4.3.2 Interplay between TISs

When analyzing the context of surrounding TISs connected with the focal TIS through various forms of competing and supportive interplay, a similar understanding and delineation of a TIS can be applied when discussing the various systems; "TISs in the context can be conceptualized in the same way as the focal TIS. They consist of technologies, actors, networks and institutions pertaining to a specific technological domain." (Bergeka, et al., 2015, p. 55). Furthermore, this section of the analysis is limited to interactions and TISs that can be considered the most pertinent through their degree of supportive- or competitive influence and interplay within the functions of the focal TIS. This means that institutional connectivity and interplay will not be addressed within this section, but within the analysis of interplay with sectors within the following section. This is due to sectors being more firmly embedded and aligned with institutional factors and actors (Bergek, et al., 2015) (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008) (Markard & Truffer, 2008) and discussing the institutional aspects related to the context of surrounding TISs and sectors should thus be simplified by addressing this aspect more or less in its entirety within section 4.3.3. Lastly, to be able to examine and explain the context of surrounding and interplaying TISs aptly, an analysis examining how each individual TIS is affecting the focal TIS, in addition to an analysis addressing the concept of several TISs interplaying together with the focal TIS has been conducted.

Interplaying TISs and the focal TIS: This aspect of the surrounding context can to a significant degree be explained through examining supportive or competitive interplay between the focal TIS and other, mainly national, TISs. TISs such as the global EV TIS, the Norwegian power grid TIS and the overarching Norwegian charging TIS in which the focal TIS exists. The global battery TIS and the global charging TIS also to some degree represents substantial direct or indirect interplay with the focal TIS. however, this interplay is arguably not as consequential and explanatory as the directly influencing ones mentioned above. Therefore, a less substantial analysis of these less significant TISs' interplay and influence will be addressed together with the intricate interplay between all relevant TISs in the next paragraph. Finally, ICT plays a significant role in relation to digital technologies such as EVs and fast EV charging (Interview.2). However, to be able to conveniently address the totality of the context within this aspect, it seems reasonable to discuss the role of ICT as a sector rather than a TIS. Since arguably several ICT-TISs could be outlined of which all of them arguably consists within the ICT-sector. Consequently, the role of the ICT will be addressed in the following section.

The Norwegian overarching charging TIS, containing other charging related TISs including the focal TIS, the home- and destination charging TIS, the assumedly forming heavy vehicle charging TIS[27] and the sea transportation charging TIS has several forms of competitive and

[27] The assumption of an emerging Norwegian heavy vehicle charging TIS is based on Norwegian goals and aspirations related to electrified heavy transportation stated in several documents including the current NTP (The Ministry of Transportation, 2016-2017) and intentions derived from public transport actor Ruter in their expressed future aspirations and strategy related to electrification and climate initiatives (Ruter, 2020).

supportive interplay related to the focal TIS. For example, the different charging TISs may compete for both financial- and human capital. Furthermore, due to the fact that several of the CPOs within the Norwegian fast EV charging market also operates within other charging markets such as home- and destination charging, fast EV charging projects may internally compete for priority and firm-related resources. Additionally, home- and destination charging may be considered a competing product to fast EV charging, since home- and destination charging in many cases may solve the same need (Interview.6) (interview.1). On the other hand, construction and development of heavy vehicle charging stations with greatly increased charging capacity related to charging output brings along with them a pertinent need for critical infrastructure development and investments (Interview.6). An additional aspect related to investments and development of the power grid arises as a consequence of sea transportation charging. This type of charging is often taking place in rural areas where grid development and capacity is weak. These charging TISs may therefore have a shared interest in developments and investments in underlying critical infrastructure necessary to conduct any form of fast charging. Furthermore, an increased number of actors entering the overarching charging TIS may increase political capital and the TISs capabilities to influence soft infrastructure and related institutions.

The global EV TIS affects the focal TIS through 2 main aspects, including incremental improvements related to technology, price, user experience and performance such as lower energy consumption, improved range (The Norwegian EV Association (a), 2019) (Figenbaum & TØI, 2018), and new capabilities related to ICT embedded into the car itself, contributing to further digitalization of modern EVs (Interview.3). The incremental improvements arguably affects the rate of adoption as well as increased usage through reduction of for example range anxiety or charging times due to for example increased charging capabilities within the EVs (The Norwegian EV Association (a), 2019) (Figenbaum & TØI, 2018). Consequently, this incremental aspect can be deemed mainly supportive, since it contributes to drive EV adoption and usage, which again drives fast EV charging market growth. Digitalization of EVs, however, rises other challenges related to communication within aspects such as ownership related to customer dialog and transactions related to for example new and digital services or charging (Interview.2) (interview.1). The shift within the role of the car producers and their EVs may lead to conflicts between for example CPOs and car manufacturers regarding transactions and dialogues related to the customer and the process of charging their vehicle (Interview.3). Therefore, at least at the time of writing, this aspect can be deemed as potentially competitive interplay in terms the global EV TIS's influence towards the focal TIS.

The power grid TIS and incremental improvements through increasing degrees of digitalization should assumedly be considered as supportive interplay in relation to the focal TIS. This is because increased digitalization of the power grid may lead to efficiency improvements as well as lower peak loads (Interview.5) (Interview.2). An aspect which should contribute to lower costs related to power grid usage within the context of fast EV charging stations. Furthermore, increased connectivity between the power grid and electrical artifacts such as EVs through digitalization enables increased use of smart technology. Creating new business models by for example using EVs, their batteries and connection to the grid as energy storage to decrease peak loads or store energy to be sold at a later point when prices increase (Interview.2).

Intricate interaction between relevant TISs and the focal TIS: Interplay between the focal TIS and surrounding and influencing contextual TISs is not only described by analyzing how an individual TIS such as the global EV TIS interplays with the focal TIS. All aforementioned TISs also to some degree interplays, competes, supports and affects each other. The global battery TIS may, through for example developing more efficient and capable battery technology, increase efficiencies in EVs within the global EV TIS in addition to improving battery storage solutions related to the Norwegian power grid TIS. Meaning that the global EV battery TIS not necessarily interplays with the focal TIS directly, but interplays and influences other contextually significant and interplaying TIS such as the global EV TIS and the Norwegian power grid TIS.

The interplay between the most relevant TISs encompassing the surrounding and influencing context related to interplaying TISs in regard to the focal TIS, is best explained by illustrating this aspect in a model. The model below illustrates the different surrounding TISs and their supportive and/or competitive interplay with other TISs and the focal TIS.

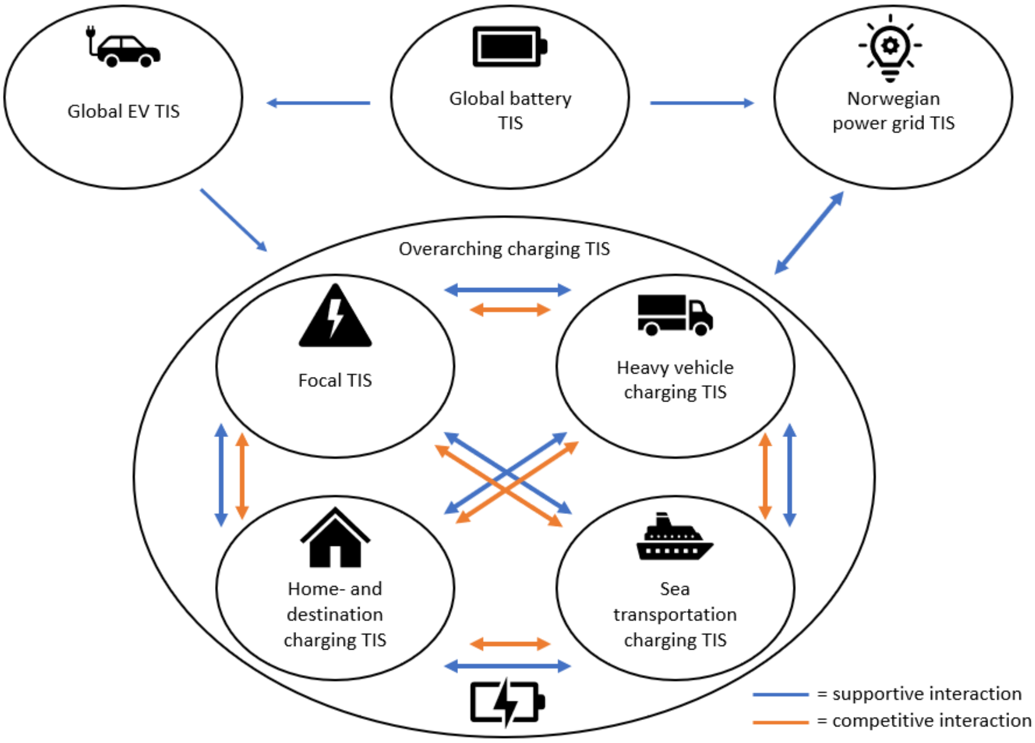


Figure 8) ***Overview of interplay between relevant TISs and the focal TIS.*** **The figure illustrates an overview over relevant TISs whom contributes to explain the surrounding and influencing context of the focal TIS by demonstrating their interplay with the focal TIS and other relevant TISs through supportive and/or competitive interplay. The type of interplay between the different entities is Illustrated in the shape of blue or orange arrows.**

As can be observed by studying figure 8) above, 4 charging related TISs makes up the overarching Norwegian charging TISs' internal interplay through both competitive and supportive interactions. Furthermore, we can observe how external TISs such as the global EV TIS and the Norwegian power grid TIS interplays via supportive interactions by for example increasing the potential of the specific technology and technology applications within the overarching charging TIS. lastly, the global battery TIS supports other supportively interacting TISs by providing these TISs with potential increases in efficiencies and technological capabilities by developing and supplying incrementally improved batteries.

4.3.3 Interplay with sectors

The focal TIS's interplay with sectors can be determined by investigating 2 main aspects. One aspect ascertains to what degree a TIS can be considered embedded or external to an interplaying sector. The second aspect involves explaining interaction between a sector and the focal TIS by examining relevant interplaying *technological assets*, *actors* and *sector-level institutions* (Bergeka, et al., 2015, p. 57). In this case, the focal TIS mainly interplays with 3 central sectors; the transportation sector, the energy sector and the ICT-sector.

The degree of embedment of the focal TIS in relation to the ICT-sector can be considered quite low. Even though ICT capabilities are important (Interview.2), they do not necessarily represent a majority within common and highly prioritized activities of most of the CPOs. Since their core business can be defined as building, developing and operating fast EV charging stations (Interview.3). Fortum on the other hand arguably has a deeper embedment into the ICT sector than other CPOs in the Norwegian market, as they also serve as an IT-provider selling various applications and services related to EV charging. In terms of relevant actors, technological assets and sector-level institutions, use of ICT-knowledge as well as being subject to data-related institutions and laws such as online privacy and The General Data Protection Regulation (GDPR) are the most pertinent examples of interplay between the ICT sector and the focal TIS.

The transportation sector represents a greatly more connected and influencing sector related to the focal TIS. The focal TIS is also arguably to a higher degree embedded within the transportation sector due to its core technology and technology application addressing energy needs related to artifacts within this specific sector. Furthermore, roads and real estate, which can be considered essential parts of a charging station, can also in many ways be considered parts of the transportation sector. Furthermore, the focal TIS can be considered a subject to various institutional laws, documents and actors within this sector. Such as for example SVV, The NTP and The Ministry of Transportation in general with its various institutional actors and agencies. Lastly, other actors such as car retailers and manufacturers, The Norwegian EV Association and other transportation related associations such as NAF originates within this sector.

In terms of the focal TIS's interplay with the energy sector, this connection can be considered the most embedded one of the 3 relevant sectors providing context and influence. For example, actors within the energy sector, such as for example utility companies or energy companies, serves in some cases as both suppliers as well as active investors creating learning spaces for the new technology through for example the initiation of projects related to fast EV charging (Interview.2) (interview.1). Furthermore, utility companies manages the power grid as well as access to and use of it. These actors also produce and sell energy through the power grid. Communication between the focal TIS and its CPOs and various aspects of the energy sector is also of great importance. An interplay which will arguably become increasingly significant as digitalization of EVs, charging stations and the energy sector increases, a manifold of opportunities for business models and increases in capabilities and efficiencies of scale may emerge (Interview.2). In terms of relevant technological assets, the power grid and communications artifacts- and capabilities are relevant examples when examining the interplay between the focal TIS and the energy sector. Sector-level institutional actors include market governing institutions such as NVE and The Ministry of Petroleum and Energy.

4.3.4 Geographical context

National landscape factors and the geographical context surrounding the focal TIS can be summarized into 2 governing aspects. Including demography and traffic patterns and energy supply and electricity infrastructure. Landscape factors would also arguably include various structural couplings, such as for example a firm which develops a technology with close relations to a university within for example national borders (Bergeka, et al., 2015). However, since no occurrence of fast EV charging technology development has been found in Norway during this analysis, together with the fact that institutional alignment and embedment of the focal TIS can be considered immature, analysis of the geographical context beyond the 2 aforementioned aspects seems potentially unfruitful and has therefore not been conducted.

Norwegian demography, in this specific case referring to occurrence of the Norwegian population throughout the country, is greatly affecting the traffic pattern since occurrence of EVs can be considered directly correlated with the occurrence of potential EV owners and drivers. Furthermore, the number of people in a current area assumedly increases the degree of traffic within that area (Interview.6). Consequently, a long-stretched country has led to arguably either rather rural or rather densely populated areas including the main cities and country sides within Norway. This in turn have led to a great variance of EV occurrence throughout the nation. A fact which can be observed in graph 5), section 1.6.4, where the majority of EVs occurs in the southern part of Norway. Highly concentrated in Oslo, Bergen and Kristiansand (SSB, 2019). Consequently, greatly increasing EV- and fast EV charging station usage in these areas. However, in the districts, a small occurrence of EVs is hurting the commercial viability of potential fast EV charging station projects since, as stated by Pedersen; “EV density per charger is the main driver for fast EV charging station profitability” (Interview.2). Even though public financial support on initial investments are potentially available via for example Enova or local municipalities, operational long term profit seems non-existent in rural and northern areas due to a lack of EV adoption (Interview.6) (Interview.3). For example, Gotaas states the following regarding fast EV charging station profitability in rural areas throughout Norway; “As stated by several CPOs, even with 100 % investment costs covered by Enova, operational viability is non-existent, making these projects uninteresting." (Interview.5).

When it comes to the aspect of energy supply and critical infrastructure, Norway has access to cheap and clean hydro energy due to its large and well-established energy sector and natural resources. Consequently, Norway is already highly electrified compared to other countries as per discussed in section 1.6.3. Furthermore, the high degrees of electrical energy consumption has led to a significantly developed power grid infrastructure relative to other countries throughout Europe (Interview.6) (Interview.2). Furthermore, the existence of a well-developed electrical distribution network has created favorable premises for the home charging market in Norway. As opposed to other less electrified markets (ibid). Home charging can be considered a competing product compared to fast EV charging. In some ways, home charging can even be considered a barrier for profitable operations of fast EV charging stations. As underlined by Gotaas; "Home charging is a significant factor influencing profitability of fast charging stations."(Interview.5). Even though home charging has been a substantial explanatory factory for current EV adoption (The Norwegian EV Association (b), 2019), it represents a dilemma since it arguably contributes to decrease commercial viability of fast EV charging stations by taking up a significant share of the charging market (Interview.6). In 2019, 65 % of Elbilisten respondents stated that they don't need fast EV charging (The Norwegian EV Association (a), 2019). Furthermore, 80 % stated that they have access to a private parking lot with charging capabilities (ibid). Additionally, Lima points out that

> It is unique for Norway to have home charging through for example access to your own garage and driveway, as opposed to other economies where it is harder to install home charging due to denser population and less access to for example garages and driveways (Interview.7).

4.3.5 Political context

The political context of the focal TIS contributes to explain its institutional alignment, which entails, among other aspects, alterations in regulation, norms and believes in addition to political support (Bergeka, et al., 2015). Political support can be summarized as follows;

> Political support for a TIS materializes in, for example, the availability of public financial resources for research and development and the formation of markets, but also in increased societal legitimacy for the technological field that positively impacts

> on the entry of new actors that bring resources to the focal TIS, such as investors, entrepreneurs and local governments (Bergeka, et al., 2015, p. 9).

The political context related to the focal TIS embodies both political support as well as initial institutional alignment. Enova's financial support initiative designed to induce fast EV charging development throughout the nation by covering some, or even all, of initial investments related to construction of fast EV charging stations, is a significant example of both institutional alignment and political support. Especially considering this institution has a separate allocation of funds within the Norwegian state budget which it manages on behalf of The Norwegian Government (Enova (b), 2019). Furthermore, relevant research within institutions such as TØI and Sintef is occurring. Research which is funded by other governmental financial institutions such as The Norwegian Research Council as well as various private actors (FuChar, 2020) (TØI, 2020). Additionally, alterations and influence towards new and existing regulations and laws are increasingly taking place as associations such as Drivkraft Norge, Virke, Footprint and The Norwegian EV Association in combination with firms like the CPOs are pooling their resources for political efforts (Interview.4) (Interview.2) (interview.1). Leading to for example a revised version of the existing energy tariff related to use of the Norwegian power grid. Where peak loads related to fast EV charging will be measured daily rather than once a month. Potentially leading to a significant reduction in costs and financial operational risk compared to the former tariff cost structure, especially within rural areas (The Norwegian EV Association, 2020) (Drivkraft Norge, 2020).

In short, we can observe how political influence-, capital and competence has increased through the development of the focal TIS. Leading to political support in the form of financial programmes and incentives, funding of relevant research and institutional alignment by positive alterations to existing soft infrastructure, including tariffs as a consequence of political efforts.

4.4 The functions and functionality of the focal TIS

In this section, an analysis of the focal TIS's functions and functionality will take place on the basis of previously analyzed aspects such as delineation of the focal TIS, its structural components and surrounding and influencing context in combination with various data sources and evidence collected throughout the research process.

4.4.1 Knowledge development and diffusion

Knowledge development and diffusion generally refers to performance of the focal TIS's knowledge base and its evolution. Distinguishing knowledge between technological, scientific, design knowledge, logistics, market and production. These types of knowledge generally originates from different sources such as R&D, learning from new applications, production and imitation (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008, s. 414). Since little to no knowledge or knowledge development related to development and generation of fast EV charging technology has been found within Norway during the analysis, combined with this study's scope and research questions arguably focusing on diffusion and utilization of fast EV charging technology through commercialization at charging stations, this section will mostly be concerned with knowledge and knowledge development related to commercialization of what can be considered fairly established fast EV charging technology. Knowledge often related to areas such as logistics, market, production and design knowledge, rather than technological and scientific knowledge. Furthermore, relevant sources of knowledge arguably mostly consists of learning from new applications, production and imitation.

When it comes to scientific knowledge, this type of knowledge mostly occurs within aforementioned research institutions such as TØI and Sintef. This type of knowledge assumedly is diffused through for example publications and collaborations related to the research projects. In terms of the projects and the knowledge developed within them, the ELAN project lead by TØI states the following project purpose: "Enhanced and accurate knowledge on the diffusion of electric vehicles and on the innovations and strategies required to reach Norway's ambitious national goals for the low emission society." (TØI, 2020).

Furthermore, Sintef leads the FuChar project. The goal of this project is to reduce necessary investments related to grid operating costs and grid integrations of electric transportation (FuChar, 2020). Including charging infrastructure for both light- and heavy battery driven vehicles and vessels. The project aims to accommodate this goal by focusing on 3 explicitly stated areas of research;

> 1) Analysis of transport patterns, user behavior and charging profiles from electric vehicles including heavy duty vessels. 2) Development and testing of alternative system configurations and control systems for increasing utilization of flexibility in

charging infrastructure. 3) Development of methods for optimal planning and operation of charging infrastructure in the distribution grid (ibid).

In terms of relevant technological knowledge and knowledge development, only cases of development and generation of AC chargers has been found within firms such as Zaptec and Easee within the Norwegian charging industry. Lima states that "A lot of knowledge and personnel within Zaptec originates from for example ABB, oil engineers and graduates from The University of Stavanger" (Interview.7), In terms of product development and design, Lima continues "We do everything ourselves in terms of hardware, imbedded, mechanics and software. A lot of micro mechanics." (ibid). In terms of fast EV charging technology suppliers related knowledge development in Norway, Hempel states that "Norway is very far ahead on EV usage compared to other economies and is very much a learning- and experimental space for the suppliers." (Interview.3).

However, the most relevant aspects of knowledge related to further development of the focal TIS is arguably knowledge and knowledge development related increasing commercialization and diffusion of fast EV charging technology. Such as for example knowledge within market development and development of charging stations within aspects such as logistics, production, imitation and perhaps the most significant form of knowledge, learning from various applications. For example, Gotaas argues that; "There is currently still a lot of learning by doing, there is a need for increased knowledge across all aspects of fast EV charging to achieve good solutions." (Interview.5). Lima refers to knowledge development within the focal TIS as follows; "Norway has been a test-market" (Interview.7). Furthermore, Circle K Charge points to acquiring commercial knowledge as one of the main reasons to establish themselves within the Norwegian charging market; "We are looking for commercial learning and developing a product and service that is relevant for EV-owners, as well as understanding potential profitability of these car drivers." (interview.1).

Political knowledge is an important and influential aspect as it increases political capabilities of the actors within the TIS which again contributes to institutional alignment of institutions such as for example NVE (NVE, 2020). Development and access to political knowledge is seemingly generally occurring within associations such as for example Drivkraft Norge, NAF, Virke, The Norwegian EV Association and Footprint. Through for example being engaged as political and collaborative agents through acting as networks and participating in political activities such as hearings (Interview.4) (interview.1). Furthermore, several associations engages in knowledge and knowledge development through for example having actors such as Drivkraft Norge conduct analysis on behalf of their member-organizations (Interview.5). Additionally, The Norwegian EV Association conducts research through their annual membership questionnaire which is applied to various forms of research such as publications made by TØI and the ELAN-project (Interview.4).

4.4.2 Influence on direction of search

In short, the function of *influence of direction of search* can be explained by applying Bergek's 4 aspects of analysis; 1) beliefs in growth potential, 2) incentives from suppliers and producers, 3) regulatory pressures and 4) expressed interest from significant customers (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). Furthermore, when considering *the influence of direction of search*, the concept of various essential actor's entrance into a TIS needs to be understood by investigating the motivating factors driving these actors' reasons for wanting to be a part of the emerging TIS (ibid). The growth of a TIS is largely driven by making itself desirable for new entrants. The new entrants in turn contributes to the TIS's growth and development (ibid). Motivating factors and the new entrants can both be of national and international origins. However, I have strived to limit the extent of this function within national actors and factors in line with the scope and delineations of this study.

Beliefs in growth potential related to the focal TIS generally stems from a few main drivers. The main driver for making the emerging TIS of fast EV charging stations in Norway attractive and desirable for new entrants is arguably the massive potential for current and continual growth of the Norwegian fast EV charging market (Interview.5) (Interview.3). This potential growth is largely driven by increased EV adoption combined with widespread use of EVs throughout Norway. Insinuating both an increase in number of EVs as well as increasing amounts of use and applications of these EVs related to solving transportation. As previously disclosed in section 1.6.4, the Norwegian EV market has experienced an incredible growth. Since EV usage is directly influencing the need for fast EV charging stations (Interview.6), or as stated by Gotaas; "The most important driver for EV charging is number of EVs and continued development" (Interview.5), the massive growth of number of EVs in Norway acts as a significant incentive for actors to get in on the action. Furthermore, Hempel argues that "When all car producers submitted to EV tech in 2015-2016, this triggered a strong belief in EV market and growth." (Interview.3).

In terms of incentives from suppliers and producers, this aspect can be briefly summarized as the continued development of performance, price and availability related to relevant technologies such as EV and fast EV charging. Although, similar positive developments within connected and influencing technology such as ICT, power grid and batteries should also contribute to improve incentives related to EVs and fast EV charging as the technologies evolves and improves. For example, initial fast EV chargers was unproportionally large, unreliable, heavy and expensive, enabling the entrance of new suppliers such as Alpitronic into the marketplace, offering specialized and designed products (Interview.3). As opposed to module-based products built from existing inventory by suppliers such as ABB. Referred to by Hempel as “Frankenstein-products” (ibid). Furthermore, car company’s motivation springs from maintaining relevance related to industry disruption and claiming a stake in a growing- and increasingly digital market (Interview.3) (Interview.2).

Regulatory pressures can be considered explicitly expressed by both institutions such as the EU through for example The Paris Agreement as well as the Norwegian government and their climate goals. Norway has for example considerable taxes related to ICEVs in addition to a comprehensive incentive structure for EVs (Figenbaum, 2017).

Expressed interest from significant customers can be summarized as market needs expressed through purchasing- and consumption patterns from Norwegian users. By examining Elbilisten 2019, we can observe how climate concerns and economic incentives are significant motivators for EV purchase (The Norwegian EV Association (a), 2019). Furthermore, EV-owners planning to use their EV for longer trips and vacations has increased significantly the last years (ibid). A change in user-patterns which potentially leads to a greater demand for charging infrastructure and continued development of EV range capabilities to reduce charging anxiety and discomfort related to fast EV charging (The Norwegian EV Association (b), 2019) (Figenbaum & TØI, 2018).

Lastly, actors like Fortum and Grønn Kontakt entered the market based on a view of the electrification transition taking place within Norwegian transportation as “A golden opportunity to acquire a national network rather cheap combined with a strong belief in technology and market.” (Interview.3). Although, combined with an understanding that “We will not necessarily earn money on this, let’s see what this may bring us” (ibid). Circle K charge on the other hand, entered the market based on the following sentiment; “Stay relevant for the modern customer, of course profitability, but first and foremost maintain the customer.” (interview.1).

4.4.3 Entrepreneurial experimentation

To analyze and understand entrepreneurial experimentation, an examination of new entrants and diversifying established firms can be conducted (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). Initially, Fortum and Grønn Kontakt represented the majority of the fast EV charging market which developed around 2011 (Interview.3) (Interview.2). Later, additional utility companies followed suit, including BKK, Lyse and Ringerikskraft. Furthermore, recent new entrants such as the EU-funded car company venture Ionity, Circle K and German utility company E.ON entered the Norwegian market (The Norwegian EV association, 2020). Pedersen states that; “There are at least 5 significant CPOs related to fast EV charging in Norway and possibly 10 or even 20 significant CPOs operating within AC charging.” (Interview.2).

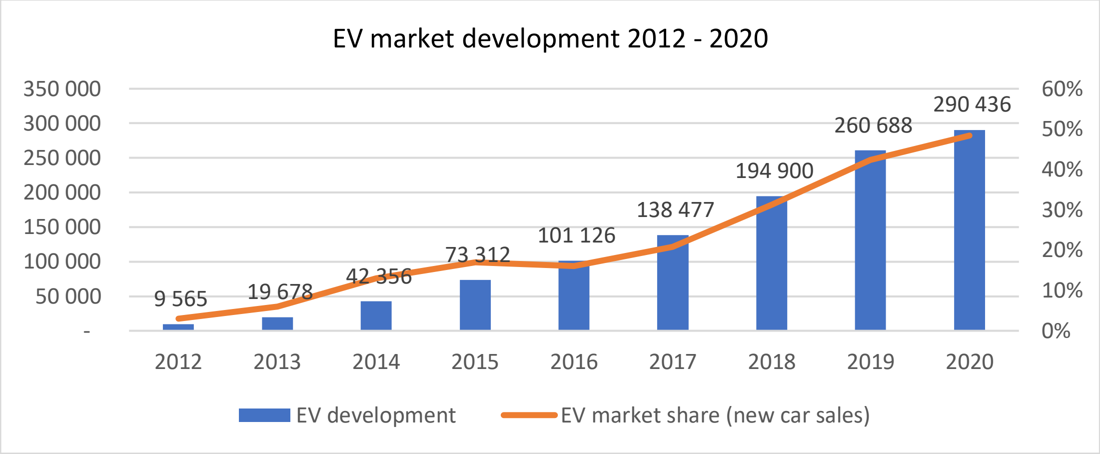
A challenge related to entrepreneurial experimentation is dependency on foreign and global suppliers. For example, collaborating with incumbent enterprises like ABB, FAC and Tritium can be difficult since requesting alterations and adaptations related to their fast EV charging technology and products is seemingly difficult for them to accommodate (Interview.3). Furthermore, both Grønn Kontakt, Fortum and Circle K charge strives to remain pragmatic in terms of suppliers, by experimenting with several products and manufacturers (Interview.3) (Interview.2) (interview.1). Furthermore, Hempel points to the fact that; “Suppliers origin from areas where there does not exists EVs.” (Interview.3). Which can lead one to question the legitimacy of current suppliers whom can be described as large and incumbent enterprises whom only recently has started engaging in fast EV charging technology (ibid).

4.4.4 Market formation

The focal TIS’s function of market formation can be examined by means of 3 aspects; 1) understanding articulation of demand, 2) analyzing market size, market development and market drivers to then enable 3) a categorization of the current market stage (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008).

In terms of market size and development related to the Norwegian fast EV charging market, relevant metrics would arguably be number of EVs as well as number of available fast- and lightning chargers and their development over time. Since number and density of EVs can be considered the main driver of fast EV charging needs and commercial profitability of fast EV charging stations, as per established in section 4.4.2. Consumers purchasing and using EVs can thus arguably be interpreted as *user- and buyer articulation of needs* related to charging.

Additionally, a metric based on number of EVs per fast- and lighting charging point arguably would illustrate relative development between EVs and fast- and lightning charging, contributing to explain market development.

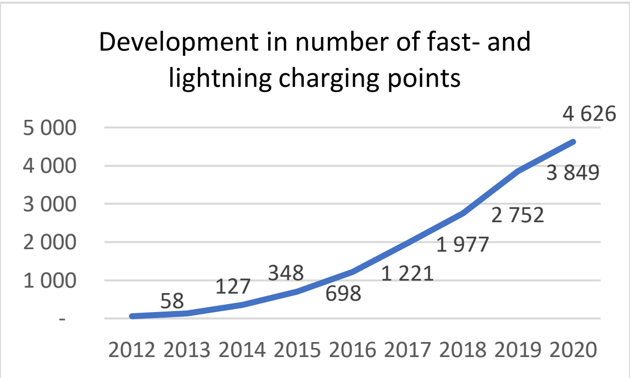


Graph 12) ***EV market development 2012 – 2020.*** **The graph illustrates the incredible growth of number of EVs and their market share of the new car sales market in Norway from 2012 – 2020** (The Norwegian EV Association, 2020)**.**

The Norwegian EV market has experienced tremendous growth due to various factors such as Norwegian consumer's climate concerns and an arguably very successful incentive policy related to EVs (Figenbaum, 2017) (Interview.4) (Interview.3) (The Norwegian EV Association (a), 2019). The Norwegian EV market currently consist of over 290.000 EVs and has achieved a 48 % share of the new car sales market so far in 2020 (The Norwegian EV Association, 2020). Consequently, the Norwegian EV market can in many ways be considered to be in a stage of early mass market. Although, uncertainties exists related to availability and quality of for example charging stations as well as maintaining EV incentives to a degree that protects the financial incentive for buying EVs (Interview.4). A highly relevant aspect based on for example Grøndahl's argument on the matter; "Continued EV sales is a highly determining factor for the fast EV charging market development and usage, and economic incentives is the most important one when purchasing an EV." (ibid). Additionally, low taxes, low costs of ownership, low costs related to usage and a lucrative initial price of the EVs are mentioned as significant triggers for EV purchases (The Norwegian EV Association (a), 2019). On the other hand, time spent charging, lack of range and poor options related to charging has been stated as reasons for not using an EV (ibid). Furthermore, increased access to fast EV charging has been pointed out as a main driver for current hurdle of EV-usage related to long distance driving (Interview.4) (Interview.2) (Figenbaum & TØI, 2018) (The Norwegian EV Association (b), 2019).

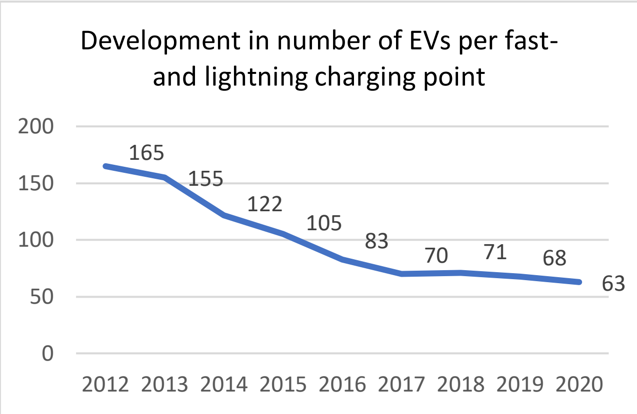
In terms of the Norwegian fast EV charging market, number of fast- and lightning chargers has also experienced significant growth alongside creation of learning spaces leading to commercial know-how as well as initial institutional alignment. For example, receiving substantial amounts of EU-sanctioned governmental funding through Enova's supportive programs. Additionally, all informants states that these programs have been instrumental for initial development of the general EV charging market (Interview.7) (Interview.6) (Interview.5) (Interview.4) (Interview.3) (Interview.2) (interview.1). Furthermore, Grøndahl states that; "We are very positive to current Enova area initiatives, although there still are significant challenges related to commercial profitability based on for example how the grid and energy tariffs are currently regulated." (Interview.4).

In 2020, A total number of 4.626 fast- and lightning charging points is currently available throughout Norway. Including Tesla chargers (The Norwegian EV Association, 2020). However, development and construction of fast charging stations in the districts has emerged as a challenge due to low EV density leading to a trivial traffic pattern, high costs related to grid usage and tariffs and little to no interest from CPOs to invest due to lack of long term operational commercial viability. Even though financial funding related to initial investments are still made available from Enova in selected areas (Interview.6) (Interview.3) (Interview.2) (Enova (a), 2019). For example, Hempel states that; "Some rural districts are barely financially viable even with Enova support due to grid tariffs based on effect peaks." (Interview.3).



Graph 13) ***Development in number of fast- and lightning charging points 2012 – 2020.*** **The graph illustrates the development of number of fast- and lightning charging points throughout Norway with a potential output of over 50 Kw** (The Norwegian EV Association, 2020)

When it comes to development in number of EVs per fast- and lightning charging point, an important driver for further EV adoption (The Norwegian EV Association (c), 2019), a stagnation has occurred as of sometime between 2016 – 2017. This stagnation may have occurred due to several factors, including changes in Enova's funding programmes focusing to a larger degree on rural locations in the districts with lower EV density and usage (Interview.6) (Interview.2), combined with leading market leaders such as Fortum and Grønn Kontakt taking a step back to assess their now firmly established market positions within Norway (Interview.3). However, several new national and international CPOs has entered the



market and a continued reduction of EVs per fast- and lightning charging point is probable given a continued increase in EV density and usage. For example, Grøndahl points to recent positive development as; "Degree of development of EVs per fast EV charger has positively increased as of late." (Interview.4).

Graph 14) *Development in number of EVs per fast- and lightning charging point.* The graph illustrates development in number of EVs divided by number of available fast- and lightning charging points with potential output over 50 kW (The Norwegian EV Association, 2020)**. As can be observed by the graph, significant reduction in number of EVs per fast- and lightning charging point was achieved in the time period between 2012 – and 2016. However, a stagnation has since seemingly become the norm for this metric within the Norwegian market.**

In short, both the Norwegian EV market and the Norwegian fast EV charging market can be considered to be well beyond a *nursing market* and have arguably established themselves somewhere between a *bridging*- and *mass market*. The EV market in particular can be considered to have reached an early stage of *mass market* by claiming a record high market share of over 50 % of new car sales in Norway being EVs in 2020 (The Norwegian EV Association, 2020). The charging market, however, has experienced stagnation to some degree in the time period between 2016 – 2019. Although, based on some continued public financial support through Enova combined with explicit and ambitious goals related to fast EV charging station development stated by actors like Ionity, Fortum and The Norwegian Government, development towards an early *mass market* related to fast EV charging in Norway seems probable.

4.4.5 Legitimation

The function of legitimation can be examined and analyzed by applying Bergek's 3 central aspects of legitimation; 1) The strength of legitimacy related to degree of alignment between a TIS and relevant legislation in addition to value base in society and industry. 2) How legitimacy influences legislation, firm behavior and demand. 3) what and who, that effects and influences legitimacy combined with how this influence and effect is practiced (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008).

Strength of legitimacy related to alignment between the focal TIS and relevant institutions and legislation can in many ways be considered moderate. During the analysis, only a few, although highly significant, challenges related to legislation or regulation has been found. While on the other hand, implementation of considerations regarding fast charging is currently being imbedded in various governing laws such as the planning and building act (Ministry of Local Government and Modernisation, 2020). Issues related lack of institutional alignment, regulation and laws is mostly occurring within 2 aspects; interplay with the grid and general institutional alignment.

In terms of the interplay between fast EV charging and the power grid, the cost structure of current energy tariffs in addition to grid investments to handle peak energy output of for example charging stations is a substantial commercial obstacle through greatly increasing financial risk and costs related to fast EV charging station projects (Interview.4) (Interview.3) (Interview.2). In short, this commercial barrier may incur significant costs within both initial investments and long-term operations related to fast EV charging stations. Nonetheless, a highlight within this aspect is an increase in political capital and political capabilities between actors such as CPOs, associations and various other firms within the focal TIS. This increase in political influence has led to, among other efforts, political activities related to for example public hearings regarding current governing and regulating soft infrastructure. These efforts has seemingly led to positive alterations of current and future regulation of interplay and use of the Norwegian power grid (NVE, 2020) (The Norwegian EV Association, 2020) (Drivkraft Norge, 2020) (Interview.4) (interview.1).

In relation to the second aspect of institutional alignment, if we consider the surrounding and influential context of the focal TIS analyzed in section 4.3, the multiplex environment in which the focal TIS politically and functionally operates within becomes evident. Since the focal TIS is emerging and existing among several TISs, sectors and established regimes, the political landscape arguably becomes complicated to navigate and influence. Hence, institutional alignment represents a challenge.

A lack of standardization of several aspects of fast charging such as ICT, payment solutions and technical specifications related to charging- and EV technology is seemingly contributing to hamper a high quality customer experience in addition to increase costs and difficulty of doing business within the Norwegian market (The Norwegian EV Association (b), 2019) (Interview.3) (Interview.2). For example, Grøndahl argues that; “It would be very positive to get an overarching direction on standards to, among other aspects, address user concerns.”, as well as pointing out the importance of EU standards such as directive 2014/94/EU (Interview.4). Furthermore, Hempel explains that; “Standards are very important, Tesla have attempted to adhere to them but due to the standards lagging behind they have been forced to go ahead outside of them.” (Interview.3). Furthermore, a lack of for example ICT standardization and clarification of roles has arguably contributed to create conflict within ownership of dialogue related to charging an EV as well as paying for charging at charging stations (Interview.3) (Interview.2). For example, several of the CPOs offer their own siloed payment solutions in addition to their own charging apps- and maps. Furthermore, communication and interplay between various artifacts such as the chargers, EVs and the power grid may experience unnecessary challenges related to scaling unless an increase in standardization takes place (Interview.2). Additionally, Pedersen argues that; “A lack of an overarching plan within fast EV charging marked development may hurt the development of standards.” (ibid). These arguments are most likely also true for charging technology as a whole. Since a multitude of solutions of fast EV charging, as well as heavy vehicle- and sea transportation charging, may be siloed, small-scale, individual and closed rather than a large-scale, connected, open and smart system (Interview.3) (Interview.2). As pointed out by Pedersen; “The government should ensure 1 standard in relation to for example heavy electric vehicles, imagine having 4 different bus companies operating between Oslo and Kristiansand on different standards." (Interview.2). A measure which should greatly improve legitimacy of the focal TIS and the application context of fast EV charging technology.

In terms of value base in society and industry, the value of fast EV charging can be measured by for example its ability to form new markets, support EV adoption and diffusion, contribute to reach global and national goals related to electrification of transportation and addressing climate issues. Arguably contributing to an overall increase of legitimacy.

How legitimacy influences legislation, firm behavior and demand is challenging to analyze. Mostly due to the fact that legitimacy of both charging technology, EVs and the focal TIS can be categorized as recently emerging and therefore practices little to moderate legitimacy and influence. However, legitimacy related to for example up time, technical issues and availability of fast chargers has been unsatisfactory according to EV owners (The Norwegian EV Association (a), 2019), and is probably hampering positive development of legitimacy (Interview.4). As stated by Gotaas; “ICT is central for the success of charging stations. A huge challenge for charging stations is downtime and technical failures, since arriving at a charging station with little to no battery and the station is currently down must be very stressful” (Interview.5).

User experience related to use of fast EV charging stations has been pointed out as a major challenge in general. Hempel states that; “Tesla takes responsibility for the user experience and is more customer experience driven as opposed to the other more profit-oriented CPOs.”

(Interview.3). Furthermore, he points out that existing conflicts between various actors regarding customer dialogue and prioritization of payment solutions can be considered a; “Clear Market failure, the government should intervene. This is the same situation as previously experienced by the energy market, addressed by Siv Jensen since the parties involved didn’t manage to agree” (Interview.3). However, the lack of legitimacy related to aforementioned aspects has seemingly not as of yet managed to influence legislation or positive firm behavior.

Furthermore, in 2019, 19 % of Elbilisten respondents stated that one of the biggest downsides of using their EV was chargers being out of order (The Norwegian EV Association (a), 2019). Additionally, 32 % stated that charging was too time consuming, 32 % stated that they experienced range anxiety, 30 % stated that they experienced a lack of availability of fast chargers, 27 % stated that charging lines was a significant issue and 14 % named planning related to EV usage as a major issue (ibid). Furthermore, 64 % stated that they experienced charging lines at fast chargers sometimes or more often. Additionally, 49 % experienced that fast chargers were out of order sometimes or more often (ibid). In short, EV users has spoken and a lack of legitimacy of both EVs and especially fast EV charging is evident. A fact that assumedly affects demand of both EVs and EV charging since 71 % of Elbilisten’s respondents stated that lower costs of transportation is a main reason for making a switch to an EV (ibid). An incentive that is arguably dependent on usage for potential realization. Furthermore, other EV usage related reasons such as more climate friendly transportation (60 %), climate discount related to road tolls (62 %) and lower maintenance costs (46 %) stands out as reasons for purchasing an EV (ibid). Other interesting findings include for example the fact that charging lines mostly occur on Enova financed stations (Interview.3).

Since EV usage is a driver for several of the user stated incentives and triggers for buying an EV, enabling and accommodating EV-usage by means of increasing legitimacy, availability and quality of fast EV charging can be considered an investment in the technology as well as the climate and climate goals. Furthermore, in terms of firm or even actor behavior, firms or municipalities as potential buyers and users of EVs such as taxi companies or public home nursing, will likely follow suit. Given an increase of legitimacy and convenience related to EVs and complementary charging infrastructure (Interview.6).

Legitimacy of EVs and fast charging in Norway is probably influencing the political landscape surrounding the focal TIS. Meaning that legitimacy of the technology may lead to increased lifetime of for example governmental incentives related to EVs. Furthermore, continued or increased financial support for fast charging related development or even research within various application context of the technology, such as the FuChar project, may occur as the technology and focal TIS becomes increasingly prominent in Norway. Increased legitimacy will most likely also increase number of different actors whom wishes to engage with and enter the focal TIS. For example, Drivkraft Norge was originally an association focused on fossil- and biofuel, which at a later stage has included electric energy as part of their strategic business area as the adoption and diffusion of relevant technologies has increased and enabled a relevant market (Interview.5). Much of the same can be said regarding market entry by utility firms and fuel retailers.

What and who that effects and influences legitimacy combined with how this influence and effect is practiced can be summarized as the actors whom participate in political activities and efforts. Legitimacy, as discussed above is greatly influenced by user experience and user patterns. However, it is arguably the CPOs and the associations that practices the political legitimacy of the technology and the focal TIS by engaging in the political landscape as per discussed within the political context, in section 4.3.5.

In general, we can assume that legitimacy related to the focal TIS and charging- and EV technologies is moderate since several challenges exists related to for example, general system immaturity, institutional alignment, operational- and commercial challenges and user experience. However, as degree of adoption and diffusion related to EVs and fast EV charging is growing rapidly, their value to society becomes increasingly pertinent. While political know-how and capabilities are being developed. Based on the aforementioned aspects and arguments, the focal TIS and its legitimacy can be considered somewhat weak or moderate with positive outlook for significant increases in legitimacy in the future. Pending continued institutional alignment as well as further adoption, diffusion and use of EVs and fast EV charging alongside substantial improvements to user experience through increased availability and ease of use.

4.4.6 Resource mobilization

Through the development and emergence of the focal TIS, various resources such as human capital, financial capital and complementary assets (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008) has been mobilized to reach todays number and functionality of fast EV charging stations. The function of resource mobilization is crucial to enable any and all of the activities within a TIS. This function is therefore closely related to the function of *influence of* *direction of search*, since both of these functions has major implications when it comes to enabling technological development and transition through for example activities (ibid).

In Norway, most of the fast EV charging stations are built, owned, maintained and operated by the 10 CPOs listed in table 1). Therefore, CPOs also arguably represents the majority of relevant resource mobilization within the focal TIS. Furthermore, since several of the CPOs can be considered SOEs, the process of understanding resource mobilization is complex. However, to simplify the analysis of this function, it has been divided into 3 separate aspects within what can be defined as relevant resources. Namely; financial capital, human capital and knowledge and complementary assets.

Financial capital: In terms of analyzing access and mobilization of financial capital, this process is in this case considerably nuanced and complex since it involves a variety of public and private actors with various roles, activities and mandates. Therefore, a traditional investigation of the Norwegian market would most likely give little insight since such examination often involves looking into actors such as seed- and venture capital, their activities within the focal TIS and their contribution to mobilization of resources (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). The lack of relevance related to a traditional examination springs from the fact that several of the significant actors who invests in, formed and owns CPOs are mostly SOEs owned by Norwegian municipalities. Additionally, the CPOs also often have very close ties to more than one SOE in terms of resource mobilization.

For example, the second biggest operator of fast EV charging stations in Norway, Grønn Kontakt, is 55 % owned by Statkraft and 40 % owned by Agder Energi. Both of these utility companies can be considered SOEs. Agder Energi is partially owned by Statkraft as well as several municipalities throughout the southern part of Norway (Proff.no, 2020). Statkraft on the other hand, is fully owned by the Norwegian government (Statkraft, 2020). The story is very much the same for several of the 10 CPOs operating within Norway. Including Koble, BKK, Lyse and Circle K. Fortum Charge & Drive is majority owned by Fortum and partially owned by Infracapital, the infrastructure investment arm of M&G Plc. Fortum is a Finnish clean energy conglomerate whom operates mostly within Scandinavia. M&G Plc is a large UK investment manager involved with equities, fixed income and real estate. E.ON is another international entrant from Germany with its roots in energy and utility. Supercharge is seemingly the only Norwegian privately financed national CPO. Furthermore, both Ionity and Tesla are CPOs emerging from the car industry.

The Norwegian government represents a majority of the various actors and structural components whom may represent financial resources in relation to the focal TIS. The Norwegian Government mostly practices relevant resource mobilization through public entities and organization engaged in offering various incentives and funding initiatives. Such entities can, in combination with the involvement of SOEs, to a large extent be considered to represent the availability of public financial capital within the focal TIS. Which arguably is the most relevant aspect of mobilization of financial resources within this function. Furthermore, public resource mobilization often takes place in the form of direct financial capital as well hosting public tenders for fast EV charging stations through Enova. Through public tenders, Enova has attempted to address the lack of fast EV charging infrastructure along the main land-transportation corridors throughout Norway by covering up to 40 % of the investment needed to build charging stations in such areas (Enova, 2017). In 2019, Enova restructured their financial support system and utilizes a different methodology to address further adoption of EVs in areas where the adoption is relatively lagging behind (Interview.4) (Interview.3). Enova is now attempting to address this issue by hosting a series of public tenders for projects involving construction and operation of fast EV charging stations. Forming a charging network covering whole counties in selected areas throughout Norway (Enova (a), 2019). The initiative has had some challenges as it forces CPOs to take on vast projects, as opposed to incremental market driven developments. For example, a tender running in 2019 covering the county of Nordland was cancelled due to a lack of participants, as one tender experienced 0 eligible offers (Enova, 2020).

Furthermore, by investigating Enova’s activities and statements in their annual report from 2019, it seems like their focus is shifting from increasing the number of fast EV charging stations, towards stimulating adoption related to heavy-duty vehicles and services such as electric buses and public transportation (Enova (b), 2019). For example, In 2019, 24 out of 47 projects regarding all EV infrastructure was funded, including funding for fast EV charging stations, amounting to 7 million NOK. In the same year, a record total of 5.8 billion NOK were distributed throughout Enova’s project portfolio (ibid). Leaving the 7 million invested in all categories of EV charging relatively less impressive. Furthermore, Enova states that; “The fast EV charging market seems to be experiencing decent growth and favorable commercial conditions” (Enova (b), 2019, p. 53). Similar statements are made in terms of limited public intervention (The ministry of transport, 2019). Which is arguably worrisome since availability of public incentives and capital arguably represents a substantial amount of historic and current financial resource mobilization. Finally, this type of resource mobilization could prove to be instrumental in further development of the focal TIS, since business cases related to construction of new fast EV charging stations vary to a great extent from case to case (The ministry of transport, 2019) (Interview.3) (Interview.2).

Human capital and knowledge: Mobilization of Human capital and knowledge-resources related to fast EV charging in Norway is mostly concentrated within operations and commercialization of fast EV charging stations. As opposed to generation and development of fast EV charging technology (Interview.3) (Interview.2) (interview.1). Furthermore, aforementioned resources seems rather available, while also having been acquired through experimentation and learning by doing (ibid).

Complementary assets: This aspect refers to recruitment of complimentary products, services and network infrastructure (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). In terms of services and products, a great extent of various applications and services such as charging maps and payment solutions has emerged together with the development of the focal TIS. Thus, mobilization of complementary products and services can in many ways be considered ongoing, although they in many cases are rather siloed and small-scale. Network infrastructure however, appears to be more of a challenge since engaging in network related activities such as political influence and acquiring political capital and capabilities can be resource demanding (interview.1). Political resources has to an arguably increasing degree been recruited and made available through political coalitions, collaborations and capabilities, which has been formed as a result of political efforts by means of coordinated measures through networks such as Drivkraft Norge, The Norwegian EV association, NAF, Footprint and Virke (Interview.5) (Interview.4) (interview.1). Even though this aspect of resource mobilization related to complementary assets pose a challenge related to political influence and institutional alignment, relevant resources and capability to utilize them is seemingly increasing, though can arguably be considered at an initial stage.

4.4.7 Development of positive externalities

The function of *development of positive externalities* is In many ways based on- and dependent on the previous 6 functions. This is because the number and types of new entrants entering and interplaying with the focal TIS greatly contributes to explain this specific function. Since, firms, actors and their interplay with the focal TIS is necessary to create positive externalities (Bergek, Jacobssen, Carlsson, Lindmark, & Rickne, 2008). This function in turn greatly contributes to explain functions such as *legitimacy, influence of direction of search, market formation, knowledge development and diffusion, resource mobilization* and *market formation.* Additionally, the function of *development of positive externalities* illustrates how these other functions are or can be strengthened (ibid). Thus, this function may be seen as a form of indicator of how well the other functions within the focal TIS are operating (ibid).

As can be observed by the many variants of relevant and interacting firms, actors and institutions found when analyzing the structural components of the focal TIS in section 4.2, the focal TIS has demonstrated a significant ability to attract both national and international, relevant and influential actors. Furthermore, an increase in the variance of different types of actors whom have chosen to enter the focal TIS has seemingly occurred as of the later stages of the TIS's emergence. Case in point, during the initial emergence of the focal TIS only utility related firms were engaging in fast EV charging technology through establishing experimental projects such as Fortum Charge & Drive and Grønn Kontakt (Interview.4) (Interview.3) (Interview.2). As of 2020, several national and international associations, car companies, fuel retailers, private equities, VCs and networks in addition to institutional actors such as The EU, The Norwegian Government and its municipalities, ministries, agencies, research institutions, regulatory institutions and SOEs has entered the focal TIS with various sentiments and roles. Several of these new entrants has arguably contributed to create positive externalities by strengthening one or several functions within the focal TIS.

For example, the emergence, entrance and engagement of associations such as Drivkraft Norge, The Norwegian EV Association, NAF, Footprint and Virke has arguably increased the political power of the focal TIS (Interview.5) (Interview.4). Contributing to strengthen the functions of *market formation* and *legitimacy* by both demonstrating political capabilities as well as increase institutional alignment by positively influencing the development of regulations within governing institutions such as NVE and its energy and power grid tariffs (NVE, 2020). Political influence which in turn may improve commercial conditions.

Furthermore, development of governmental financial support through institutional actors such as Enova and municipalities in combination with an increase in number of CPOs operating within both the focal TIS as well as the overarching charging TIS has seemingly contributed to reduce negatively influencing and impending aspects and increase the functions of *legitimacy, market formation* and *influence of direction of search* related to EV usage by reducing range anxiety and increasing ease of use by means of offering services and products related to charging in general. Increased EV usage legitimacy through use of charging technology, can in many ways be seen as a foundation or premise for current EV adoption in Norway by having greatly influenced fast EV charging market development and the focal TIS's *influence of direction of search*. Much in the same way fast EV charging can be viewed as a premise to overcoming the final hurdle of EV adoption, diffusion and utilization as the dominant technology within the Norwegian car park and the sole vehicle within households, while also serving as a convenient choice for long distance transportation (Figenbaum & TØI, 2018) (The Norwegian EV Association (b), 2019) (Interview.4).

A prevalent increase of national governmental engagement related to the focal TIS within *resource mobilization* through for example financial support towards research programmes such as ENERGIX and the FuChar- and ELAN projects, also speaks magnitudes towards the development of the function of *legitimacy* of both the focal TIS and the relevance of application and diffusion of its technology. *Legitimacy* based on societal value which is arguably being demonstrated through such measures. As a consequence, a strengthening of functions such as *knowledge development and diffusion* may occur alongside consequential *entrepreneurial experimentation.* Additionally, mobilization of financial-, scientific and political resources from international institutions such as The EU contributes to invoke further international and national general mobilization across several functions of the focal TIS. Through, for example, the establishment of ventures such as Ionity as well as development of soft infrastructure such as standards in addition to modernized and adapted regulation and laws. Enabling large scale and long-term investments and developments related to charging- and charging technology, as well as connectivity, communication and collaboration by integrating smart ICT-solutions (Interview.2). Potentially greatly increasing the functions of *market formation* and *legitimacy* in addition to boost the transitional power of the national and global charging TIS.

Although the focal TIS is experiencing significant increases and strengthening of functions and functionality, not all is well when considering future outlook related to further emergence and development. For example, vital institutional actors such as municipalities experience challenges related to how to address and take advantage of these new technologies (Interview.6). As pointed out by Gotaas; "The municipalities are challenged since they have a great responsibility, but they may lack capabilities and knowledge in relation to charging technology while also experiencing a lot of insecurity." (Interview.5).Furthermore, limitation of financial funding in relation to for example Enova support and EU regulations may hamper engagement of, among other initiatives and actors, municipalities through denying direct financial support of fast EV charging station projects (Interview.6). A potentially negatively influencing impending aspect hampering further development within several of the focal TISs functions. Since municipalities may operate within roles such as local regulators, investors, customers and users in relation to fast EV charging (ibid). Potentially inhibiting positive development of *market formation, legitimacy,* and *resource mobilization* within the focal TIS.

In terms of technology generation and development by foreign and international suppliers, Hempel states that; “Development of fast EV charging technology is disconnected from the user experience and the CPOs.” (Interview.3). A factor which may greatly diminish several of the focal TIS’s functions due to its clear dependency on external suppliers, especially *legitimation*.

Furthermore, a lack of standardization and overarching governmental planning within ICT, purchasing processes, technical specifications of charging stations and EVs may lead to a multitude of small scale, siloed and disconnected solutions, products and services related to fast charging in general. Including heavy vehicle- and sea transportation charging (Interview.6) (Interview.2).This is because most fast charging technology application-contexts and related industries and markets are subject to several of the same premises and factors such as soft infrastructure, use of critical infrastructure, *resource mobilization* and processes of *legitimation.* A fact which may hurt the process of *legitimation* and *market formation* in the long run by potentially hampering the technological advantage of being a digital and modern infrastructure in addition to complicating and reducing value and benefits related to large-scale rather than small-scale initiatives and developments (Interview.2). For example, a new paradigm within fast charging is arguably taking place in Norway as large firms, institutional actors and SOEs such as Ruter and other heavy vehicle transportation actors are looking to accommodate national and global climate efforts and goals by transitioning to electrical buses and heavy-duty vehicles (Ruter, 2020). Taxi-firms are another example of actors whom are considering a transition to EVs, though highly dependent on availability of high capacity fast EV charging infrastructure (Interview.6). Furthermore, as EV charging capabilities are increasing, CPOs such as Ionity and second-generation technology and products with lightning charging capabilities up to 350 kW are entering the market (Ionity, 2020). Replacing what is often being referred to as first generation fast EV charging infrastructure (Interview.7) (Interview.3) (Interview.2).

Both lightning- and heavy-duty vehicle charging has distinctly different operational conditions when it comes to underlying infrastructure and use of the Norwegian power grid compared to much of existing fast EV charging infrastructure with capacity between 50 – 150 kW. Conditions which are often incurring vast costs related to power grid investments to accommodate needs related to peak capacity. Which, under today’s regulations, laws and market orientation has to be covered by the single actor whom is triggering the need for critical infrastructure investments (Interview.3). Arguably inhibiting large scale charging stations (The Norwegian EV Association (b), 2019) (Interview.4) as well as sea-transportation charging. Which is often occurring in the power grid peripheries. As to why Hempel urges governmental engagement; “The government should look into supportive and coordinated measures related to grid investments, not only related to fast EV charging.” (Interview.3). Furthermore, Hempel points out that; “Some rural investments just simply are not profitable. However, they are very significant for user experience. Here the government must take responsibility for a dialogue with the CPOs and ensure sufficient EV user experience.” (ibid).

However, as of yet the Norwegian Government seems content with leaving fast EV charging development to private actors through a market driven approach. A position clearly expressed through for example Enova’s annual report (Enova (b), 2019), current governing NTP (The Norwegian Goverment, 2017) and the latest strategic document regarding actions related to alternative fuel infrastructure in Norway (The ministry of transport, 2019). Although, a considerably more publicly driven market development-approach, accommodating relevant actors, sectors, industries, markets and climate considerations may be a stronger approach in terms of strengthening the functionality of the focal TIS. Especially considering Norway’s arguably historic success of state-managed development of other critical infrastructure such as the current power grid and the telecommunications grid (Interview.6). In other words, as pointed out by Kristiansen; “If you want a commercially based charging infrastructure, I believe you will be able to acquire that, if you want a good charging infrastructure throughout Norway, you might have to think a bit different.” (ibid).

5. DISCUSSION

In this chapter, I start of by discussing the functions and functionality of the focal TIS by rating the fulfillment of its functions and discuss them within the context of negatively influencing impending aspects and positively influencing supporting aspects. Followed by a conceptualization and discussion of the role of The Norwegian Government and its contribution towards increasing fast EV charging technology diffusion and utilization within Norway. Finally, a concretization and discussion of main overarching barriers and drivers related to further diffusion and utilization of fast EV charging technology in Norway will take place on the basis of the surrounding and influencing context of the focal TIS and its functions and functionality.

5.1 RQ 1: What are the functions and functionality of the Norwegian fast EV charging TIS?

In short, the focal TIS's functions can be described as the roles, activities, influence and contributions of the structural components outlined within the 7 functions of the focal TIS in context of the surrounding and influencing context. System functionality can be considered as the system's performance explained by assessing and discussing the interplay of the TIS's functions as well as determining the system's phase of development. Furthermore, the aspect of identifying inducement- and blocking mechanisms will be addressed in section 5.3 within overarching barriers and drivers. Specifying key policy issues is discussed in section 5.2, within the role and contribution of The Norwegian Government.

To address the first research question more directly and in depth, an assessment of the 7 functions and the overall system performance has been conducted by discussing the degree of fulfillment of each function and its interplay with the other functions, structural components and surrounding and influencing context. Fulfillment or lack of fulfillment of each function has been illustrated by pointing out specific negatively influencing and impending aspects and positively influencing and supporting aspects, which are currently occurring within each function. Furthermore, Although negatively influencing and impending aspects and positively influencing and supporting aspects in many ways are similar to barriers and drivers related to further diffusion and use fast EV charging technology in Norway, the aspect of overarching barriers and drivers will be addressed separately in section 5.3. Since main overarching barriers and drivers can be considered the sum of several significantly negatively influencing and impending aspects or significantly positively influencing and supporting aspects within the context of both the focal TIS's function, functionality and its surrounding and influencing context. As opposed to the influencing supporting- or impending aspects, which are more concerned with illustrating internal and specific performance of the functions and functionality of the focal TIS.

5.1.1 Assessing and discussing system performance

The assessment of the functions has been conducted by firstly pointing out distinct negatively influencing and impending aspects or positively influencing and supportive aspects to thereby assign a degree of fulfillment of the function on a scale from 1 – 5. Where 1 represents *little to no fulfillment* and 5 represents *complete or close to complete fulfillment*. Secondly, a discussion of individual functions in addition to overall system functionality and performance have been conducted.

Function	Fulfillment	Positively influencing supportive aspects	Negatively influencing impending aspects
Knowledge development and diffusion	3	- High degree of recruitment of new entrants. - Increased engagement and development of networks through for example associations. - A high degree of EV density in urban areas enabling opportunities for learning spaces related to commercial and operational knowledge development. - Several examples of learning from new technological applications due to pragmatism towards technology and suppliers.	- Little to no technological knowledge development or generation found within Norway. - High dependency on external knowledge and knowledge development related to technology development and generation. - Low degree of engagement of research communities and actors. Weak connection to the technological research aspect in general. -Challenged interaction with technology suppliers.
Influence on direction of search	4	- Strong believes in growth potential. - Strong incentives driving adoption of EVs. - Maturing technology. - Climate considerations and governmental pressure. - Significantly expressed user interest and positive changes in user-patterns.	- Several competing technologies and substitutes. - Commercial challenges related to long-term operational profit and rural areas. -Lack of standardization
Entrepreneurial experimentation	3	- High number of new entrants. - Several technological applications. - Favorable conditions for learning.	- Complete dependency on external, foreign and global suppliers and knowledge related to technology.
Market formation	3	- Tremendous growth in the EV charging market as well as the premise providing EV market. - Clear articulation of demand from both users and The Norwegian Government. -Initial financial governmental support and incentives.	- Low degree of technical and political legitimacy. -High dependency on external, foreign and international suppliers. - No financial or governmental support towards increasing commercial viability of fast EV charging operations (as opposed to establishment) - Established market leaders taking a step back. -Lack of overarching plan for development -Lack of standardization
Legitimation	2	- High degree of value base in society and industry of both EV as premise providing technology and EV charging as complementary technology. - Initial political capabilities.	- Low degree of institutional alignment. - Immature capabilities related to political influence. -A lack of standardization.

			-Low degree of user-experienced technical- and operational availability. -Lack of overarching plan for development.
Resource mobilization	4	- Considerable access to financial resources. - Knowledge related to commercial capabilities seems available. - Significant engagement of various actors and new entrants.	- Low degree of access to public financial support and alternatives. -Low degree of access to political resources, knowledge and capital.
Development of positive externalities	3	- Initial governmental engagement and institutional alignment. - Strong market formation - A high degree of recruitment and introduction of new entrants. - Significant degree of resource mobilization across several aspects.	- Low degree of legitimacy - A lack of governmental mobilization - Low degree of political influence, knowledge and capabilities. - A lack of institutional alignment.

Table 4) ***Assessing system performance.*** **The table contains a overview of the 7 functions, their degree of fulfillment as well as impending and supporting mechanisms.**

The function of *Knowledge development and diffusion* is given the score of 3 based on negatively influencing and impending aspects and positively influencing and supportive aspects. Since the scope of this study is very much focused on diffusion and utilization of fast EV charging technology, which in the in the case of Norway is highly related commercial viability and market development, less significance has been given to the fact that little to no technological development or generation related to fast EV charging technology seemingly takes place in Norway. However, this fact leads to a strong degree of dependency on foreign knowledge and suppliers. Suppliers whom may have varying motivations for collaborating with Norwegian CPOs Since, several of the suppliers, such as for example Siemens and ABB, are operating as competing CPOs themselves in other markets. However, the Norwegian EV market enables great opportunities for knowledge development by attracting significant amounts of new entrants and creating learning spaces related to market, logistics, production and know-how in regard to general commercialization of fast EV charging technology. It does so by enabling and hosting the introduction of multiple technological applications within several aspects. Including aspects such as various solutions within the physical chargers, services, ICT and payment solutions.

The function of *influence of direction of search* is given a score of 4 based on several positively influencing and supportive aspects and few negatively influencing and impending aspects. Climate considerations, public pressure and involvement through incentives and regulation, together with strong growth within both the charging market and the EV market contributes to attract a substantial amount of various new entrants to the focal TIS. Despite a somewhat immature technology related to existing first generation fast EV charging stations, combined with a continued dependency and development of ICEVs alongside potential substitutes such as biogas and hydrogen. A strong, established and fast-growing home- and destination charging market is also potentially contributing to hurt commercial viability of operating fast EV charging stations.

Entrepreneurial experimentation is given a score of 3 considering the degree of technological applications due to pragmatism towards use of new and existing suppliers, access to favorable learning spaces and market conditions for commercial experimentation, in addition to the occurrence of several new entrants from various origins. However, dependency on external, foreign and often international suppliers represents a threat in relation to the function of entrepreneurial experimentation. Since this aspect of the focal TIS is out of control of the central actors within it. Furthermore, little to no entrepreneurial experimentation takes places related to fast EV charging technology generation and development but is highly concentrated on the aspect of commercial knowledge and capabilities related to market, logistics and production.

The function of *market formation* is scored at 3. This function is characterized by both significant positively influencing and supportive aspects and negatively influencing and impending aspects. In short, strong market drivers has enabled a tremendous growth in both EV- and fast EV charging adoption, diffusion and utilization, alongside initial financial and institutional support through institutional actors such as Enova. Furthermore, both the Norwegian EV market and the fast EV charging market experiences clear articulation of demand demonstrated by user purchasing- and use-patterns in addition to explicit aspirations and goals related to both technologies set by national and global entities such as The EU and The Norwegian Government. On the other hand, a lack of legitimacy related to technical and commercial aspects such as up-time and availability of fast EV charging stations, in addition to little political influence, continues to hamper user adoption and institutional alignment. Additionally, factors such as established market leaders recently taking a step back to assess current market position in addition to little access to financial and institutional support towards commercial viability related to operations in rural areas and a potentially low degree of engagement by central actors such as municipalities and county municipalities, likely contributes to slow down *market formation*.

The function of *legitimation* is given a low score of 2 due to several aspects. The main considerations are related to the lack of institutional alignment, political influence, knowledge and capital related to existing regulations such as for example energy tariffs and interaction with the power grid. The fact that CPOs still seemingly operates as a sole actor in relation to cover costs incurring due to investments related to grid improvements outside of Enova supported areas, speaks magnitude to the lack of governmental engagement and institutional alignment. Considering development of fast EV charging stations arguably is in line with general and local public aspirations and goals. Overall degree of standardization is also pointed out as a weakness in relation to fast EV charging technology. Furthermore, societal value is clearly expressed through importance of climate considerations and economic upsides of use of EVs and complementary fast EV charging infrastructure. On the other hand, discontent related to use of fast EV charging stations and technology in regard to charging lines, charging time and technical down-time is arguably a considerable aspect negatively influencing and impending the process of legitimating the technology and its commercial and technical viability. Leaving the focal TIS's function of *legitimation* a long way to go in terms of a high degree of fulfilment.

Resource mobilization is an additional highlight alongside the function of *influence of direction of search*, both functions scored at 4 with a considerable degree of fulfilment. This function seems fulfilled to a high degree based on access- and willingness to invest in fast EV charging technology as well as engaging in its diffusion and commercialization by several forms of actors. Including car companies, fuel retailers, energy companies and public entities such as The EU. Furthermore, access to commercial knowledge and human resources seems reasonably available as it has not been mentioned or found as a challenge to acquire to any significant degree. Lowlights within this function of the focal TIS is related to a lack of political resources, capital and capabilities in addition to governmental engagement. The focal TIS has seemingly only recently acquired emerging capabilities to significantly influence its surrounding political context. Furthermore, access to institutional and public resources related to for example financial capital when considering relevant research projects or financial support for fast EV charging projects with low commercial potential due to high grid investment costs and unreasonable operational costs through energy tariffs, seems rather inadequate.

The function of *development of positive externalities*, which in many ways can be viewed as an overall assessment of the functions and the dynamics of the focal TIS, is scored at 3 with a significant degree of fulfilment yet currently experiencing a substantial potential for improvement of system performance within several functions. Highlights of this function and the functionality of the focal TIS in general, is related to the development of initial governmental engagement, alignment and support, a significant degree of resource mobilization, introduction and recruitment of new entrants and *market formation*. On the other hand, the function of *development of positive externalities* can be considered hampered or threatened by the following aspects: the state of legitimacy, lack of governmental mobilization and engagement, a lack of overall political influence and a low degree of institutional alignment.

In terms of *phase of development*, the focal TIS has considerably few designated actors and networks related to political context, knowledge transfer and associations, as well as an unmet need for access to fast EV charging and a developing market with growing demand for increased capabilities of kW output. Therefore, it is difficult to argue that the focal TIS is in a mature phase. On the other hand, with the number of current fast chargers, increases in output capacity and number of new entrants combined with the impressive growth rate in number of fast charging points, it is clear that the focal TIS is not in the completely formative stage of nursing and learning either. This leaves us with the bridging phase, in which the focal TIS has reached a sufficient level of technological knowledge, mature customer base and several new market entrants to sustain significant growth, but not yet to be considered a mass market.

Although firm market formation, tremendous market growth, substantial amounts and variations of new entrants, significant resource mobilization, initial political influence and institutional alignment would point towards a favorable and continued development of the emergence of the focal TIS, issues related to system performance within legitimacy, political power in addition to a lack general governmental engagement represents substantial system impediments and sources of negative influence which may hurt the system's development going forward. To summarize, the functions and functionality of the focal TIS can arguably be classified as fulfilled to some extent with several functions such as *influence of direction of search* and *resource mobilization* being classified as significantly more fulfilled than other critical functions such as *legitimation.* Remaining functions, including *knowledge development and diffusion*, *entrepreneurial experimentation* and *market formation,* are all scored at 3 with a substantial degree of fulfillment, yet with significant potential for positive development towards complete fulfillment. Leaving the state of the functions of the focal TIS with a potentially good outlook for the future, dependent on the systems capability to overcome negatively influencing and impending aspects and continue to positively develop its functions and their interplay with structural components and the surrounding and influencing context.

5.2 RQ 2: What is the role of the Norwegian government, and how does it contribute to enable diffusion and commercialization of fast EV charging technology in Norway today?

In this section I will address the second research question by discussing the role of The Norwegian Government and how it contributes to enable diffusion and utilization of fast EV charging technology by affecting and interplaying with the focal TIS. Potential policy issues will also be pointed out.

5.3.1 The role and contribution of The Norwegian Government

The Norwegian government arguably embodies one of the most significant explanatory factors related to the focal TIS, its emergence and continued development. Potentially only surpassed in significance by the aspect of the charging technology in which the system jointly interacts to contribute to generate, diffuse and utilize in line with delineation, understanding and definition of the focal TIS. In short, the Norwegian government encompasses a multitude of roles and aspects in relation to the focal TIS. The most significant ones can be summarized and discussed within 3 main categories; regulator, overarching institutional body and advocate.

Role and contribution as a regulator: As a regulator, the Norwegian government is responsible for developing and executing overarching policy, laws, regulations and most other forms of soft infrastructure, as per explained in section 4.2, where structural components, including the Norwegian government and its subjected actors, were examined and analyzed. However, this aspect is of great importance in terms of explaining the role and contribution of the Norwegian government in relation to its interplay and influence towards the focal TIS. Thus, its role as regulator is mentioned specifically in part to point to its significance as well as enabling further discussion of its contribution and influence in relation to this role.

The Norwegian Government practices its influence and contribution in regard to the focal TIS in large part through regulations such as the planning and building act, energy and grid tariffs via NVE, standards and general oversight through various ministries and institutions. Through the role as regulator, The Norwegian government arguably contributes to enable the focal TIS by ensuring a stable socio-economical and socio-technological context in which charging technology may be commercially established, diffused and utilized. It does so by for example developing and enacting extensive incentives for new and climate friendly technologies such as for example EVs, contributing to create the current state of development of the Norwegian

EV market. Which is a significant premise provider for sound commercial opportunities for fast EV charging stations. Since EV occurrence and usage can be considered the main driver for commercially viable development and operations of fast EV charging stations. The Norwegian Government also embodies regulatory aspects related to for example security, finance, political processes as well as all other aspects of a modern society and economy.

On the other hand, most of regulations and measures related to governmental oversight, such as energy- and grid tariffs, is not developed to regulate the fast EV charging industry or market. Which in several cases contributes to significant barriers for further development of the focal TIS, as well as complicating further diffusion and utilization of fast EV charging in Norway. Although developments in several aspects of regulations and expressed aspirations in regard to governmental engagement is being, at least to some initial degree, altered to adhere to fast EV charging technology and commercialization if it. Nevertheless, as discussed within the functions and functionality of the focal TIS, arguably not to a sufficient extent.

Role and contribution as an overarching institutional body: The Norwegian government's role as overarching institutional body encompasses aspects and responsibilities such as governmental ownership and management of relevant and interplaying institutions, agencies and SOEs, governance and oversight related to the political landscape, distribution and management of public resources, knowledge development to some extent while also encompassing municipalities as potential customers, owners and users in relation to fast EV charging stations.

In terms of contribution as an overarching institutional body, The Norwegian Government's management and oversight related to regulatory institutional actors such as ministries, SVV, NVE and DSB, research and knowledge related institutions such as TØI, Sintef, agencies and The Norwegian Research Council, commercially oriented SOEs such as utilities, fuel retailers and transportation companies in addition to encompassing other institutional actors such as municipalities, which, when all are gatherer together within one institutional body, represents vast influence and contribution towards diffusion, utilization and commercialization of fast EV charging technology through numerous forms of interplay with the focal TIS. Including both positive and detrimental interactions.

Regulatory institutional actors contributes by influencing the focal TIS through for example knowledge development in addition to regulatory measures and initiatives. These actors also represents much of what can be considered to be the political landscape in which the focal

TIS is engaging in by having for example CPOs and associations undertake political actions such as developing and submitting contributions to hearings and engaging in other political platforms and networks.

Research and knowledge institutions in addition to research and knowledge funding institutions, contributes to enhance the focal TIS by increasing understanding of for example application contexts related to diffusion and increased use of fast EV charging technology. These actors also contributes to develop knowledge and understanding related to market development and market drivers through various research projects, collaborations and publications. SOEs and firms, such as for example utilities and fuel retailers, serves several roles in regard to contributing to diffusion and utilization of fast EV charging technology. For example, taking on roles and related contributions such as experimental actors, providing sources of various forms of resources such as knowledge and financial capital and acting as premise providers in relation to access to energy and the power grid. Furthermore, fuel retailers contributes to fast EV charging diffusion and utilization by engaging in for example collaborations with CPOs by providing access to real estate and lucrative charging locations, or even entering the market as CPOs themselves. Other SOEs such as Ruter and for example public home nursing actors, serves as potential large-scale customers and users. Lastly, yet highly significant, county municipalities and municipalities influences and contributes to fast EV charging diffusion and utilization by a considerable extent through interplaying with the focal TIS in several ways. This actor may contribute through serving as for example a customer, owner, users, local regulator, financial supporter or as being an advocate in a more regional and local context compared to the Norwegian Government as a whole.

Furthermore, as an overarching institutional body, The Norwegian Government has clearly and repeatedly stated their intentions of leaving diffusion, utilization and overall commercialization of fast EV charging technology as much as possible to market forces. As opposed to a state-driven market model. A model which historically has been representative for the government’s position in relation to development of other infrastructure such as the Norwegian telecommunications network and power grid. Which in many ways can be considered success stories since, Norway arguably has considerably well-developed, robust and stable critical infrastructure. Which is also a premise provider for today’s adoption, diffusion and utilization of home- and destination charging technology consequent market development. Thus, The Norwegian Government’s position on a market driven development of fast EV charging may in several ways serve as a barrier to several functions of the focal

TIS by for example contribute to deter governmental- and institutional engagement and support.

This raises the question of whether or not a market driven approach is necessarily the optimal method when developing national and potentially critical infrastructure. Although charging infrastructure, in terms of its role and use in Norway today, should arguably be considered less critical than the power grid and the telecommunications network. However, this may not be the case in the future as Norwegian transportation continues its rapid transition to becoming wholly electrified, with an increasing reliance on charging infrastructure. Finally, by distancing themselves from engaging in diffusion, utilization and overall commercialization of fast EV charging technology by advocating a market driven approach, The Norwegian Government may have created a vacuum in terms of overarching planning and responsibility of something as considerably complex and intertwined within several aspects of society such as a potentially critical, digital infrastructure network of fast EV charging stations throughout the nation.

Role and contribution as an advocate: As a frontrunner for EV adoption and usage, acting as a host for the emergence and development of the focal TIS in addition to enabling critical learning spaces and initial commercial opportunities related to fast EV charging, The Norwegian Government can in many ways be considered an ardent advocate of EV- and charging technology. Although not necessarily expressed to a great extent through direct measures and initiatives related to development and commercialization of fast EV charging stations, The Norwegian Government has clearly expressed its ambitions related to electrification of the Norwegian transportation sector. Furthermore, it has been acting as an advocate through financial institutions such as Enova in addition to greatly incentivize EV adoption and diffusion. On the other hand, The Norwegian Government has arguably been somewhat struggling to address how to increase utilization of EVs in regard to the final hurdle of EV utilization related to household dependency as well as making EVs a preferred choice of transportation for long distance travel as opposed to current usage. A challenge where fast EV charging stations stands out as a logical and viable solution to address this final hurdle. Additionally, securing development of a fast EV charging network should enable a path for developing large scale high-output infrastructure for heavy vehicles in the near future. In line with The Norwegian Governments goals and aspirations related to further and future electrification of the Norwegian transportation sector.

In general, the role of The Norwegian Government can be somewhat roughly summarized as a regulator and overarching institutional body whom in many ways regulates the focal TIS via incumbent policies and regulations, often developed within established sectors and regimes. Furthermore, The Norwegian Government strives to advocate both EV- and charging technology while attempting to accommodate a market driven fast EV charging infrastructure development. Although, with arguably mixed success as reduction in number of EVs per fast- and lightning charging point has been fairly stagnant in Norway since 2016. Furthermore, initial and current Enova managed financial programmes has to some degree succeeded to almost induce a national fast EV charging network of charging stations. On the other hand, current Enova programmes are seemingly struggling to induce further development of fast EV charging stations in northern rural areas. Since no eligible bids were committed in the previous competitions for financial Enova support. Furthermore, initial infrastructure developed in part by means of original financial Enova programmes, are facing an increasing degree of antiquation when compared to current and future EV charging capacity. Even more so when compared to for example Ionity's and Tesla's current charging capacity in addition to their future aspirations. Thus, The Norwegian Government is facing the emergence of a potential need for a second-generation charging network to accommodate modern EVs, user patterns and eventually heavy-duty electric vehicles like buses and trucks.

In short, the role of The Norwegian government can be outlined to some degree as an enthusiastic, yet to some extent incompetent or even negligent regulator, overarching institutional body and advocate in relation to the focal TIS and its emergence and development. Furthermore, The Norwegian Government arguably attempts to distance itself from directly partaking in diffusion, utilization and general commercialization of fast EV charging technology to a significant extent. However, it has had substantial success through for example financial Enova programmes in addition to EV incentives. Incentives and financial support which are contributing to drive the need for- as well as commercial profitability and sustainability of fast EV charging stations. Finally, the current role of The Norwegian government arguably represents several barriers in relation to further development of the focal TIS's functions and increased diffusion and utilization of fast EV charging technology. As opposed to simply acting as a favorable source of influence contributing to drive positive development of the focal TIS by accommodating fast EV charging technology diffusion and utilization, via for example increasing commercial viability of fast EV charging stations or addressing legitimacy issues such as current lack of standardization.

5.3 RQ 3: What are the main overarching barriers and drivers for further diffusion and utilization of fast EV charging technology in Norway?

Overarching barriers and drivers can be considered significant and often complex factors and mechanisms which represents substantial blocking- or inducing mechanisms in relation to further development of the focal TIS as well as influencing the surrounding and influencing context of it.

5.2.1 Main overarching drivers

Main overarching drivers can be addressed by discussing 2 greatly consequential and positively influencing aspects; EV adoption and usage and political pressure combined with changes in values and general advocacy.

The most significant driver for diffusion and utilization of fast EV charging technology on fast EV charging stations in Norway is unequivocally current state and development of EV adoption and utilization. This aspect has been repeatedly pointed out as a main explanatory factor for commercial viability of fast EV charging stations. Often through the metric of number of EVs per charging point. Furthermore, EV adoption and utilization explains traffic pattern and serves as the main premise for charging needs. This driver is seemingly based on current existence of the arguably greatly successful Norwegian incentive system for taxing ICEVs and providing favorable conditions for EV adoption through for example reduced toll expenses, exemption of taxes and increased rights by for example being able to take advantage of the taxi and bus lanes when driving an EV. Access- to and quality of fast EV charging is also found as significant explanatory factor for EV adoption and utilization.

The second greatly consequential and positively influential overarching driver is related to global and national political pressure, changes in values and a general advocacy of for example electrification technologies such as EV- and EV charging technology. International collaborations such as The Paris Agreement and political pressure from explicit expression of aspirations and goals by entities and agencies such as The Norwegian Government and The EU represents immense influence towards changes in values and inducing advocacy of for example RETs and cleantech in general. As previously discussed in section 5.2, The Norwegian Government can be considered an ardent advocate of, among other electrification- and climate-oriented technologies, EVs and fast EV charging. Furthermore, measures such as The Paris Agreement seemingly contributes to underline the existence and impact of climate related issues. Arguably contributing to drive changes in user values and behaviors as well as influencing and recruiting actors such as various firms. For example, climate concerns is one of several significant reasons for purchasing an EV. Furthermore, firms like utility companies and fuel retailers align themselves with climate efforts by engaging in TISs like the focal TIS and taking part in potentially supportive interplay within all of the focal TIS's inherent functions and overall functionality through for example *resource mobilization, knowledge development, entrepreneurial experimentation,* and *market formation,* through hosting experimental projects, operating as CPOs and making various forms of resources available. Contributing to drive further diffusion and utilization of fast EV charging technology and EVs by making charging technology available to the market via developing fast EV charging stations. Arguably greatly contributing to the transitional momentum of both technologies towards a green and sustainable economy.

5.2.2 Main overarching barriers

Main overarching barriers can be summarized within 3 major aspects in regard to substantial blocking-mechanisms and potential negative influence towards the focal TIS, its functions, functionality and its surrounding and influencing context; current geographical context, lack of *legitimacy* and current degree of public engagement.

The geographical context of the focal TIS within the borders of Norway is related to the degree of home charging and current traffic pattern. Although, strong development of the home charging segment in many aspects is a positive circumstance for electrification of Norwegian transportation, in addition to serving as a premise for current EV adoption, it has been repeatedly pointed as a significant barrier for development of fast EV charging stations. Since home charging arguably contributes to reduce their commercial viability by taking up sizable market shares, seemingly substantially reducing the need for- and use of charging stations throughout Norway. This barrier may be compounded by the nature of Norway's demographics and EV density, which seemingly leads to unfavorable traffic patterns related to fast EV charging stations based on EV usage and density in for example rural areas. While on the other hand, fast EV charging has been deemed commercially viable in most urban areas.

As can be observed by the assessment of the functions and functionality of the focal TIS, the function of *legitimacy* is significantly unfulfilled and underdeveloped. This aspect arguably represent an overarching barrier, since for example the lack of quality related to user experience may hamper fast EV charging technology utilization and continue to enable conflicts of interests between different actors within the focal TIS. Furthermore, arguably initial institutional alignment seemingly struggles to address, or positively influence issues related to the fact that the focal TIS is emerging within several incumbent regimes. More specifically its ability to for example address aspects such as existing grid tariffs and interplay with the power grid in general, as well as falling behind on standardization. Furthermore, this lack of political capabilities may hinder the focal TIS from sufficiently engaging and influencing the surrounding political context in general. Such as for example increase resource mobilization within relevant research or lobby forth favorable and relevant financial incentives and mechanisms. Little fulfillment of the function of *legitimacy* may also discourage potential new entrants from engaging with the focal TIS. Finally, a lack of overall standardization related to fast EV charging technology- and stations seemingly contributes to hurt market development.

Current degree of governmental engagement and the role of The Norwegian Government related to the focal TIS in general, arguably leads to several potential and existing barriers. For example, the government's current position related to a market driven approach may leave user experience-hampering conflicts such as the conflict of interest between various CPOs and car manufactures to endure longer than necessary. Given that they do not manage to resolve this conflict by themselves. Which was not the case for the Norwegian energy market. Furthermore, not engaging in for example taking overarching responsibility for a minimal level of user experience related to access to fast EV charging through for example ensuring commercial viability of both establishing and operating fast EV charging stations in rural areas, is probably detrimental for EV adoption within such areas, as well as not encouraging complete dependency on- and long distance travel with EVs. Investments related to development of necessary power grid improvements is another aspect which arguably could be mediated by the government. Not only within the context of fast EV charging and the focal TIS, but for addressing and accommodating further electrification of Norway in general. In short, having The Norwegian Government increase their engagement within electrification in general by for example loosening their position on a market-driven approach related to development of charging infrastructure by for example coordinating overarching grid development and tariffs, promote and ensure standards and intervene with financial incentives within both establishment and operations where for example fast EV charging stations are not commercially viable.

The scenario of increased adoption, diffusion and utilization of EVs and fast EV charging technology is in many ways a catch-22 paradox, in the way that increased numbers and use of

EVs should increase commercial viability- and consequently access to fast EV charging stations. Which in turn should induce further EV adoption and utilization. Thus, by having The Norwegian Government invest in and secure EV- or fast EV charging development, they will potentially ensure continued development of both aspects.

6. CONCLUSION

In this chapter I attempt to conclude the research of this study by addressing limitations of the research, pointing to specific policy recommendations and discussing suggestions and implications for further research. Finally, I will attempt to summarize and concretize the various aspects, analysis and findings of this paper by means of a few contemplated concluding remarks.

6.1 Limitation of research

As pointed out by Albert Einstein; “Not all that counts can be counted”. A saying which is highly applicable when considering the scope and delineation of this study within the context of the limitation of its research. Firstly, this study is significantly oriented towards diffusion and utilization of fast EV charging technology via its commercial viability on public charging stations throughout Norway. Since little to no know relevant technology development and generation takes place in Norway, consideration towards knowledge and knowledge diffusion, which is often viewed as central when discussing the emergence of an industry, is hardly addressed. Furthermore, due to the fact that relevant and commercialized technology is seemingly solely developed by foreign and international suppliers, this aspect of the study has received little attention. This is due to the fact that available fast EV charging technology can be considered established enough in terms of its capability to accommodate market needs, while this aspect also does not represent major barriers for further development of the focal TIS. although it arguably does represents a significant threat and potential barrier due to dependency on foreign and international suppliers.

Furthermore, due to the nature and complexity of a system-analysis combined with the resources inherent in one researcher represented by me, this study can hardly be considered exhaustive in terms of its investigative capabilities and findings. Furthermore, the analysis serves the research questions and attempts to align itself with the scope and delineation of this study. These aspects therefore also serves as limitations of this study.

Lastly, a thorough discussion of factors such as a market-driven approach as opposed to state-driven approach has not to a large extent been included. This is due to for example limitations to the format of the size of this particular study combined with the fact that such as discussion could entail its own research paper in its own regard. This aspect is also true in terms of for example various roles and contributions as well as potentially taking an in-depth look at the political landscape and context surrounding the focal TIS.

6.2 Policy recommendations

In terms of policy recommendations, several suggestions and considerations has been pointed out by the informants as well as potential suggestions making themselves prominent throughout the analysis and discussion chapters of this study. Most of the significant findings within barriers and negatively influencing aspects are arguably related to the role and contribution of The Norwegian Government and the power grid through their interplay and influence in connection to the focal TIS and its functions, functionality and surrounding and influencing context. The recommendations can therefore be discussed within the 2 governing aspects; interplay with the power grid and overarching governmental engagement.

In terms of interplay between the focal TIS and the power grid through for example various forms of establishment- and operational costs, adaptations and considerations towards fast EV charging as a separate, unique and emerging industry and market could be developed to address its specific characteristics and particular commercial challenges. As suggested by several actors such as The Norwegian EV Association, Footprint, Drivkraft Norge and Virke through for example political hearings, as well as being pointed out by several informants, incumbent institutions such as NVE and its regulations regarding energy tariffs and frame work for incurring investment costs in relation to increased needs and capabilities within the power grid, is representing a significant barrier for further development of fast EV charging stations. Particularly related to initial investment costs and long-term operational commercial viability. Although most often in rural areas. Furthermore, in addition to leading up the second policy recommendation, having The Norwegian Government mediate and take responsibility for overarching development of the power grid in line with ongoing green transition and climate goals- and aspirations, could be considerably favorable for several industries, markets and aspects within the Norwegian economy.

In terms of overarching governmental engagement, increasing degree of governmental market-intervention within barriers and examples of weak system performance and functionality, such as a seemingly siloed development of user experience-related tools and services, including real time charging maps, charging applications, a multitude of payment solutions in addition to a significant conflict of interest, could arguably be highly beneficial. Intervention which would ensure a high-quality user experience and resolve conflicts of interests. For example, a similar market failure related to the conflict of interest within the energy market between grid companies and energy companies was resolved through establishing Elhub. A central IT-system which facilitates and streamlines market processes such as electricity sales. A concept which potentially could be applied to facilitate and streamline market processes related to fast EV charging. Furthermore, the dynamics of these market processes are also considerably similar since, they both encompass interplay with the grid and consumption of electric energy. Additionally, improved user experience could be ensured by increased governmental intervention within commercially unattractive and unsustainable areas. These areas are often rural but may be highly significant to facilitate EV utilization by increasing long distance travel and making EVs the preferred choice for vacation travels.

Furthermore, having the government take main responsibly for development and adherence to standards could significantly improve several functions of the focal TIS by for example enabling development and execution of large-scale projects, induce communication and connectivity, increasing ease of doing business and substantially improve *legitimacy* of fast EV charging technology- and stations.

Finally, empowerment of- and knowledge development within municipalities could contribute to increase the significance and impact of this central actor by for example developing purchasing standards, guidelines and framework related to EV- and charging technology. Furthermore, increasing flexibility and alternatives within governmental financial incentives and support, while also addressing the need for operational financial support and not only offer financial support related to initial investment costs, could greatly improve commercial viability of charging stations throughout the nation.

6.3 Suggestions and implications for further research

When it comes to suggestions and implications for further research, this aspect should arguably be highly connected with the limitations of research within this specific study. Since some aspects and conceptualization related to the focal TIS has been given little to no attention. Although this prioritization does not mean these left out aspects are without relevance. Even though they arguably are of little relevance of this specific study in line with its scope, delineation and research questions.

Either way, implications of this study are for example looking into how one could support the focal TIS by addressing overarching barriers and enforcing overarching drivers. Furthermore, suggestions for further research could for example address some of the more intriguing aspects in relation to the focal TIS whom has been given little attention within this study.

Such as for example researching the potential upsides and downsides of a market-driven approach compared to state-driven approach related to diffusion and utilization of fast EV charging technology in Norway. Additionally, an investigation into whether or not Norway should attempt to facilitate local technology development and generation of fast EV charging technology could be of interest. Since our current capabilities and knowledge related to electrification of transportation could for example be a potential source valuable export. Lastly, an in-depth understanding of the role of county municipalities and municipalities, as well as how these central actors can be empowered to increase development of the focal TIS could be of interest.

6.4 Summary and concluding remarks

This study strives to answer its research questions by applying a qualitative and system-oriented framework to a social phenom in the form of a green transition related to electrification of Norwegian transportation. It has done so by first and foremost putting the specific phenom in context of innovation theory and thereby develop a specifically adapted framework based on relevant analytical tools and concepts. Tools and concepts such as relevant and applicable aspects of for example conceptualization of infrastructure in society in addition to system theory-based TIS- and MLP-approaches. Data- and evidence collection has been conducted through for example document analysis, semi-structured expert interviews, databases and to some extent descriptive data to be able to develop empirical findings by applying this data to *the tailored analytical framework* through the qualitative methodology and research design applied within this case study.

Furthermore, conceptualization and concretization of the system of which is seemingly, at least in part, responsible for facilitating further electrification of Norwegian transportation through diffusion and utilization of fast EV charging technology by means of developing and commercializing fast EV charging stations throughout Norway, has been conducted. The conceptualization and concretization process was conducted on the basis of the process of analyzing this system through 4 central aspects; delineation and definition of the system, analyzing its structural components, conceptualization and analysis of its surrounding and influencing context and finally, an analysis of its functions and overall functionality. Through this process, the focal TIS was delineated and defined within the aspect and application of fast EV charging technology as the main unit of analysis and technology context. Furthermore, conceptual borders of the focal TIS was established within the geographical borders of Norway, in addition to develop a compiled overview of relevant actors within its value chain.

At this point, structural components, including various actors, networks and institutions, was analyzed. Revealing the significance of relevant firms and entities within the TIS such as the CPOs, associations, various regulating and governing institutions, knowledge-related actors and the substantial role of The Norwegian Government.

Furthermore, the surrounding and influencing context of the focal TIS was conceptualized and analyzed. Contributing to establish the importance of the interplay and influence of for example landscape factors such as the ongoing global pandemic and changes in values and norms related to global climate considerations. Other significant concepts and findings within the surrounding and influential context of the focal TIS includes; the dynamics and significance of the interplay between the focal TIS, the overarching charging TIS and the externally interplaying TISs related to EVs, batteries and the power grid. The interplay and embedment of the focal TIS within sectors such as the ICT-, transportation and energy sectors. How the geographical context contributes to complicate and hinder commercial viability of fast EV charging stations due to for example taking up market shares combined with Norwegian demography representing several rural areas with little commercial viability related to fast EV charging stations. Due to for example low EV density and high investment- and operational costs occurring based on interplay with the power grid. Finally, a lack of institutional capabilities and alignment was found by analyzing the concept and dynamics of the political landscape related to the focal TIS.

At this stage, an analysis of the functions of the focal TIS was conducted. The function of *knowledge development and diffusion* is mostly concerned with taking advantage of learning spaces and entrepreneurial experimentation by for example applying several application context of the technology while also developing commercial capabilities and know-how. The function of *Influence of direction of search* is affected by for example a significant belief in growth potential, political pressure, expressed customer interest and strategic sentiments. *Entrepreneurial experimentation* is mostly driven by new entrants from industries such as utility, fuel retail and the car industry. *Market formation* seems strong on the basis of current EV adoption and utilization in Norway. However, development in reduction of number of EVs per fast- and lightning charging point has seemingly stagnated since sometime between 2016 and 2017. The function of *legitimacy* seems challenged by a multitude of aspects. Including for example low degrees of institutional alignment, standardization, political influence and challenged user experience based on a conflict of interest, low availability of fast EV charging stations in rural areas, little governmental engagement and high degrees of technical challenges and downtime related to fast EV charging. *Resource mobilization* seems to have come along way as access to capital and commercial human capital seems rather available. A weakness within this function is degree of mobilization of political resources and coordination. The function of *development of positive externalities* can in many ways be summarized as the overall functionality and performance of the system. In short, this aspect of the functionality of the focal TIS experiences a high degree of new entrants, significant resource mobilization, high dependency on foreign suppliers and technology developers, a lack of standardization and legitimation in general.

At this stage, a discussion of the research questions in context of the focal TIS and related empirical findings within the analysis chapter has been conducted to address the research questions in-depth. In short, the functions and functionality of the focal TIS was found to be fulfilled with varying degree within different functions. For example, *influence of direction of search* and *resource mobilization* can be considered fulfilled to a significant degree. Furthermore, *knowledge development and diffusion, entrepreneurial experimentation, market formation* and *development of positive externalities* was found to be moderately fulfilled with significant potential for improvement in function performance. Lastly, the function of *legitimacy* was found to be the least fulfilled and poorest performing function within the system. Representing several potentially detrimental barriers and significant negative influence in relation to the overall functionality of the system.

Furthermore, the role of The Norwegian Government and its contribution has been discussed in line with the second research question. In short, the role and contribution of The Norwegian Government can be summarized within the aspects of acting and contributing as a regulator, overarching institutional body and advocate. In general, a potential lack of governmental engagement was found in relation to several aspects of incumbent soft infrastructure, interaction with governmental bodies and public infrastructure and a potential lack of governmental market-intervention, standardization and financial incentives.

Lastly, a conceptualization and discussion of main overarching barriers and drivers has been conducted in relation to increase understanding of how to facilitate further diffusion and utilization of fast EV charging technology in Norway, within the context of the focal TIS, its functions, functionality and surrounding and influencing context. In short, main drivers are considered the current state and development of EV adoption and utilization in addition to global and national political pressure, changes in values and a general advocacy. Main barriers are defined as the Norwegian geographical context, poor system function related to legitimacy and a lack of public engagement.

Going forward, in terms of facilitating further electrification of Norwegian transportation and accommodate global and national climate aspirations- and goals, The Norwegian Government's role and contributions seems essential to both address specified barriers as well as strengthening driving forces related to the focal TIS, its functions, overall functionality and surrounding and influencing context. Since overcoming the final hurdle of EV adoption in many ways arguably can be addressed by for example increasing diffusion and utilization of fast EV charging technology by securing commercial viability of fast EV charging stations throughout Norway. Furthermore, a more pragmatic and governmentally engaged market approach seems necessary to address weak system functions-, performance and functionality and strengthen the focal TIS's performance by addressing challenges and barriers related to legitimacy, commercialization and the fact that the focal TIS and related diffusion and utilization of fast EV charging technology in Norway is very much taking place within incumbent regimes.

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APPENDIX

Intervjuguide

Innledning:

Kort intro av meg, tema, oppgaven og Pathways.

1) Hvem er du, hvor jobber du og hva er din rolle i organisasjonen?

Generelt:

2) Kan du kort fortelle om din oppfatning av utviklingen av hurtigladermarkedet i Norge (fra 2010 og frem til i dag)?
    a. Hva med hurtigladeindustrien i Norge? (produksjon og utvikling av hurtigladeutstyr)

3) Hva mener du er de viktigste driverne for nåværende og fremtidig utvikling av hurtigladestasjoner i Norge?
    a. Hva mener du er de viktigste barrierene?

4) Hvilken rolle har staten hatt i utviklingen av hurtigladermarkedet i Norge?
    a. Hva mener du om denne rollen / strategien?

Aktører:

5) Hvem er de mest sentrale aktørene i hurtigladestasjons-verdikjeden i Norge? (teknologiutviklere/komponentleverandører og produsenter, eiere/operatører/driftere, interesseorganisasjoner som Elbilforeningen og NAF, samt offentlige aktører som Stortinget, kommunene, SD, Enova, NVE og SVV)
    a. **Se vedlegg 1:** Hvem er viktigst? Mangler det noen?

6) Hvilke universiteter og forsknings- og utdanningsinstitusjoner er viktig for hurtigladermarkedet i Norge?
    a. Hvilken funksjon og påvirkning har disse?
    b. Hvordan er relasjonen mellom de forskjellige aktørene og forsknings- og utdanningsinstitusjonene?

7) Hvilke nettverk og møteplasser er viktige for lademarkedet i Norge?
    a. Finnes det dedikerte nettverk for hurtiglading? Eller finnes dette mere for lading og elbiler generelt?

8) Hva slags (nasjonalt og internasjonalt) lovverk, regulering, direktiver og standarder er viktig for hurtiglading i Norge?
    a. Hvilke aktører utvikler og utøver disse?

9) Hvilken rolle har kraftsektoren i forbindelse med utbygging og drift av hurtigladestasjoner? (hvem må operatørene forholde seg til, hvordan?)
    a. Hvilken rolle har transportsektoren?
    b. Hvilken rolle har den IKT-sektoren?

10) Hvordan er kunnskap og samarbeidsevne i forhold til å kunne imøtekomme videre utvikling av hurtiglademarkedet i de forskjellige sektorene?
    a. Kraftsektoren
    b. Transportsektoren
    c. IKT-sektoren

11) Er politikk og regulering i forhold til IKT, vei og kraftsektoren forenelige med utbygging, drift og bruk av hurtigladestasjoner? (for eksempel, er kraftsektorens lover og regler – konsesjon og tariff i forbindelse med NVE – en pådriver eller en hindring for utbygging og drift av hurtigladestasjoner?)
    a. Hvordan er samarbeidet mellom aktørene i de forskjellige sektorene, snakker de sammen?
    b. Hvordan er kunnskapen i de forskjellige sektorene i forhold til utbygging og drift av hurtigladestasjoner?
        i. Hvor finnes det eventuelt mangel på kunnskap?

12) Hva finnes av insentivordninger og andre politiske virkemidler for å stimulere utviklingen av hurtigladestasjoner i Norge?
    a. Hvilke aktører står bak disse ordningene?
    b. Hvordan fungerer disse insentivene?
    c. Er de tilstrekkelige?
    d. Finnes det eksempler på insentiver eller virkemidler som burde vært tilgjengelig, men ikke finnes?

13) Hvordan er tilgangen til ressurser for hurtiglademarkedet med tanke på:
    a. Kunnskap og arbeidskapital (hvor vanskelig er det å finne ekspertise eller gode kandidater med relevant utdanning og eventuelt erfaring?)
    b. Hva med tilgang til kapital? (eksempelvis: Hvordan finansieres utbygging og drift av hurtigladestasjoner? Hvordan er operatørene av hurtigladestasjoner finansiert?)

Overblikk:

14) Hva er de viktigste momentene for videre utvikling av det norske hurtiglademarkedet?

15) Hvilken rolle burde staten ha i tiden fremover for å sikre utvikling av det norske hurtiglademarkedet?

16) Hva slags forbedringer med tanke på kunnskap burde imøtekommes for å støtte videre utbygging av hurtigladestasjoner i Norge?

17) Hvilke leksjoner kan andre markeder lære fra den norske suksessen med tanke på bruk av elbiler og utvikling av hurtigladeinfrastruktur?

Vedlegg 1 (intervjuguide): Liste over kjente relevante aktører med tanke på hurtigladermarkedet i Norge

Operatører	**Offentlige organisasjoner**	**Assosiasjoner og interesseorganisasjoner**	**Universiteter og forskningsinstitusjoner**	**Teknologileverandører**
Fortum Charge & Drive	NVE	NAF	Sintef	ABB?
Grønn Kontakt	SVV	Elbilforeningen	UiO	Siemens?
Tesla	Regjeringen	Virke	NTNU	DEFA?
EO.N	Samferdselsdepartementet	Teknisk Ukeblad (TU)	TØI	
Koble	Kommuner	Drivkraft Norge		
Supercharge	Bymiljøetaten	Standarder (NEK, ISO, IEC etc…)		
Circle K	Klimaetaten	Energi Norge		
Ionity	Enova	Smartgrid		
BKK	EU			
Lyse				