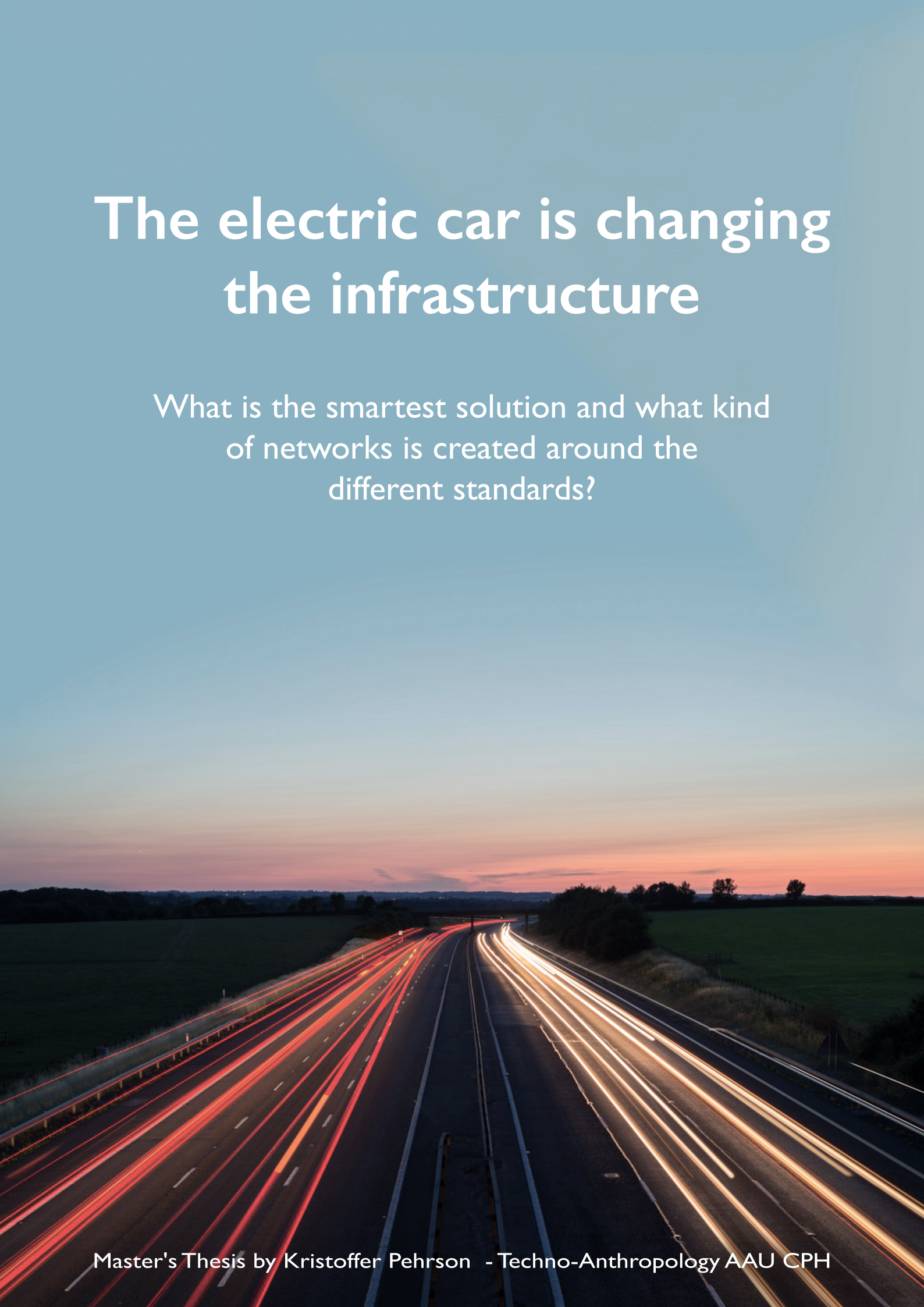
The electric car is changing the infrastructure

What is the smartest solution and what kind of networks is created around the different standards?



Master's Thesis by Kristoffer Pehrson - Techno-Anthropology AAU CPH

September 14th, 2018

Aalborg University Copenhagen
Master's Thesis
Techno-Anthropology, 10th semester

Supervisor: Christian Baron

Characters (with space): 181.276
Pages: 73

Name: Kristoffer Pehrson
Study no.: 20162916

Summary

I dette speciale undersøger jeg hvordan billedet på infrastruktur for elbiler tegner sig nu og i fremtiden.

Det viste sig hurtigt at der var en formatkrig mellem Japanske CHAdeMO og Europæiske CSS combo, som er to forskellige standarder indenfor hurtigladning. Jeg undersøger hvilke fordele og ulemper de to forskellige standarder har og ved hjælp af ANT kigger jeg på hvilke typer af netværk som danner sig rundt om de enkelte standarder.

CHAdeMO har en den tekniske fordel, at bilen både kan lade og afgive strøm. Det giver nogle spændende muligheder for at indgå i forsyningsnetværket.

CSS combo er i stand til at lade væsentligt hurtigere og har et stærkt netværk i Europa.

Tesla kører indtil videre deres eget sololøb med deres egen standard og har en ambition om at skabe et mere lukket netværk, hvor der lades op med Tesla solceller, som derefter går i husets eller bilens batteri.

Desuden viste det sig, at betalingsdelen kunne være vanskelig for kunder , særligt når de bevægede sig ud over Danmarks grænser. Derfor behandler jeg også det emne i analysen og spørger ind til, om der er behov for en fælles standard.

Jeg har gennemført fire dybdeborende interviews med fire forskellige eksperter inden for området. En fra forbrugerorganisation Forenede danske motor ejere, en fra Dansk Elbil Alliance, en fra Forenede Danske Elbilister og en fra Clever. Det har været en stor fordel, da jeg på den måde kunne få adgang til viden, som ikke findes nedskrevet i bøger, artikler og lignende. Dette gælder i særlig grad de forhold, som rækker ind i fremtiden.

Abstract

In this master Thesis, I investigate how the image of infrastructure for electric cars looks now and in the future.

From the beginning of the process it became clear that there was a format war between the Japanese CHAdeMO and the European CSS combo that are two different modes of quick loading. I investigate the pros and cons of the two different plug-standards, and using ANT I look at the types of networks that are formed around each standard.

CHAdeMO has the technical advantage that the car can charge and deliver power back to the power grid.

It provides some exciting opportunities to join the network surrounding the supply grid. On the other hand CSS combo can charge significantly faster and and beside it has a strong network in Europa.

Tesla is currently running their own solo with their own standard and has an ambition to create a more closed network where Tesla's solar panels provide power directly to the car or the Tesla battery in the house.

It turns out that to be allowed to pay for charging was very difficult for customers, especially when they moved beyond Denmark's borders. Therefore, I also treat the subject in the analysis and wonder if there is a need for a common standard.

I made 4 interviews with 4 different experts in the field. One from the consumer organization Forenede danske motor ejere, one from the Dansk Elbil Alliance, one from Forenede Danske Elbilister and one from Clever. This has been a great advantage, as I could get access to knowledge that is not to be written in any books, articles etc. This applies in particular the circumstances that reaches into the future.

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List of terms

DC direct current, the electric charge only flows one direction

AC alternating current, changes direction periodically

Type 1 and **Type 2** – two standards for normal charging

CHAdeMO – one standard of fast charging. Mostly used in Japanese cars.

CSS combo – One standard for fast charging. Mostly used in European cars.

Radial – The definition of the power cables underground that supply houses with power. One Radial will typically distribute power to 30-35 houses.

Power grid – the word that I chose to use abut the electricity supply network, that provides houses with power

Tesla PowerWall – a battery to store power from solar panels at a house.

Introduction

By the year 2020 the number of cars in the world will reach one billion. The car industry is growing and will continue growing for many years (SONG, 2018). But the problem with cars as we normally know them is the pollution: they pollute – both locally with smog and unhealthy emissions in cities and as a big contributor to global warming.

The car has for a long time been a paradox. There is a big wish in the population to reduce congestion and pollution particularly in cities. At the same time, we all buy a car as soon we can afford it. A report from the World Bank shows that at least 1.5 million people die of accidents or pollution every year. (World Bank, 2018)

In Europe there are 563 cars per 1000 persons, while USA has 791 per 1000 persons. (SONG, 2018).

There is no doubt that cars are one of the biggest pollution problems that we face in a modern society.

Something is about to change

But it seems like something is about to change in the car industry. The electric car is just about to disrupt the whole industry.

One of the biggest car brands in Europe, Volksvagen (VW) has stated that they will invest more than 520 billion in the future of the electric car (Gullev, 2018).

VW's goal is that in 2025 there will be more than 80 different electric car models on the streets (Godske, 2018).

Many of us have heard the story about Tesla that has changed the perception of electric cars by putting an exclusive car with long battery range on the market.

Tesla has put some coolness into the electric car industry, and many of us think on a Tesla when the subject is electric cars.

Tesla as a company has also had a massive increase in value the last few years. By April 2017 it was more valuable than the biggest car company in America, General Motors (GM). In April 2017 Tesla was trading with a stock price of $303.89 per share and a total market cap of $53.06 billion, while GM was trading at around $34.40 per share, with a total market cap of $49.80 billion. (TechCrunch, 2018)

Also, the demand is incredibly strong, with around 373,000 preorders as of May 2017 on Tesla's new model 3. Tesla has definitely kick started the hype around the electric car.

Later it turned out Tesla got some problems by delivering al the preorders timely but that's another story. (TechCrunch, 2018)

At the long term the future belongs to the electric car, the most banks, experts and car brands seems to agree on. This Master thesis will investigate how we deal with charging of all the electric cars. Be course it also require a totally different infrastructure then we are used to see today with gas stations. The overall picture will properly be that main charting will be home instead of outside that car owners is used to today. For longer trips there will of course still be need of something that is in some way similar to the gas stations along the roads. It is what called fast charging in the electric car business.

Motivation

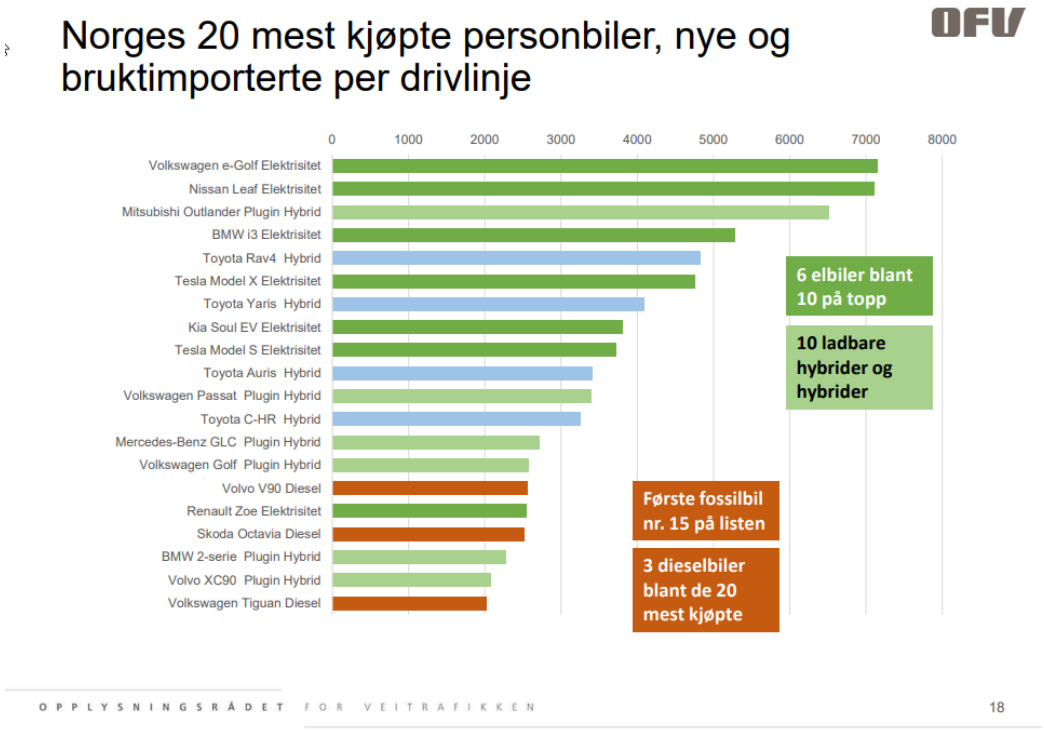
During this master project I want to work with and combine two topics that always has been my interest. First of all, something that has high impact on a society level combined with a topic that always been in my interest from when I was a small boy: Cars.
First, cars have always had my passion and, second, the way we use cars has a huge impact on society and even the planet as a whole.
It could be very interesting to combine my old interest as a boy, with the way we deal with more sustainable transport in the future.
I found that if I chose infrastructure for electric cars as a topic for my master thesis it will be a perfect combination of these two interests. And there is also good job opportunities, at this field at the future, be course the development goes fast now and a lot of big companies invest great amount of money in the development of electric cars and the surrounding infrastructure.

Problem field

Parallel with the electric car becoming more and more popular, there is also a need to build a new kind of infrastructure that fits the new need of charging, so that the car drivers experience the same level of freedom, that they are use to today. But what kind of infrastructure do we need? How powerful will the batteries be in the future? Where will the charging take place? What kind of standards and collaborations or partnerships will we see in the market? And how different is the picture from what we see now with gas stations spread all over?
It is not only a matter of what happens in the future. The development is already upon us. There is actually more electronic charging stations spread all over Denmark, then there is as gas stations. There is 2,030 publicly available charging points. By comparison, there are 2,028 petrol stations in Denmark. (Sommer, 2018).

But the sale of electric cars in Denmark is still missing out. At the first quarter of 2018, sale was 156 electric cars only. It is about 1.6 pct. of the total number of new cars sold during the same period of 2018. (Dansk Elbil Alliance, 2018)

That is not much compared to Norway, a country in many ways similar to Denmark if you look at the way to organize the society, both around cars and otherwise. But regarding sale of electric cars, Norway is way ahead of Denmark. In numbers that is 3,948 sold electric cars, that corresponds to 28 pct. of the total number of sold cars in Norway at 2017. (Ingeniøren, 2018)



The development is going fast in Norway. The numbers is car sale of new cars in 2018. The first fossil fuel car first appear as number 15 on the list. Source: ssb.no 2018

An important discussion concerning the electric car is of course the car-tax. Many actors from the electric car industry try to convince Danish politicians to hold the electric car free of taxes a bit longer, so the development and market can be pushed further.

The history of electric cars and taxes has not been stable. For many years the electric car has been hold free of tax. But from 2016 the tax exemption will gradually be phased out over the next five years to pay full tax from 2020.
After that political agreement the sale of electric cars died completely, leading to concerns among of almost all the political Venstre, Socialdemokratiet, Dansk Folkeparti and Radikale Venstre. (Skm.dk, 2018)

New complex agreement

These parties succeeded in persuading the Government to modify the tax regime for electric cars. The main feature in the new agreement was that the phasing in of taxes was put on hold until there were sold January 2019 electric cars. If there is already more then 5,000 newly registered electric cars are sold before 1 January 2019 the phase in of taxis will start from the point were number 5000 is sold, then the registration tax on electric cars is phased in as follows:
20 percent of the normal tax rate through 2019
40 percent of the normal tax rate in 2010
65 percent of the normal tax rate in 2021
90 percent of the normal tax rate in 2022
100 percent of the normal tax rate in 2023 and beyond (skm.dk 2018)

Car taxes is a very important tool, to get more electric cars out on the roads, but in this project I will only focus on infrastructure and do not discuss further the matter of car taxes.

Today in Denmark the state normally plays an important role in most of the infrastructure of any kind that surrounds us. The state has the responsibility to establish a certain infrastructure in the whole country. It could be trains, postal services, electricity and many other kinds of infrastructure.

But the infrastructure for electric cars is so far only handled by private actors. Is that a democratic problem? What does it mean for quality and the geographic distribution of infrastructure for electric cars? And will there be different standards competing against each other?
Another very relevant issue is the infrastructure below the surface: The power cables that supply the network. Right now there are many places where the cables aren't powerful enough to handle a situation where many electric cars charge at the same time. So how many and how powerful should the cables be in order to supply a future of more electric cars than we see today? Is it possible to create a prize-structure that can motivate people to charge where the most powerful cables already are located? Or maybe it is better to create a more intelligent solution? It could be a price structure or the cars themselves could contribute to the balancing of the power supply.
But one of the biggest challenges right now, especially in the investment phase, is that there are different competing charging standards in the market. Right now there are 5 types of plugins, that can fit eatch other in some way but efficient 3 competing standards – that do not fit each other. This can create some confusion for the costumers. Therefore, in this project, I will look more into the standards that are in the present market, and which kinds of network and alliances that are created around them.
All these questions have guided me to the following problem formulation:

Problem formulation

How will the infrastructure for electric cars look like in the future? Which kinds of alliances are created and what kind of network does each plug standard have?

Sub question: Is there a need for increased standardization of payment for charging?

Field boundary

One of the biggest subjects around the electric car is the discussion about car taxes. Are tax exemptions or other differences in taxation the right way to stimulate the sale of electric cars over cars with combustion engines? How much is it fair tax wise to differ from gasoline and diesel cars, should they be treated the same or is it reasonable to take the standpoint that electric cars are better for the environment and for the climate and therefore should have privileges in the form of lower car tax, free parking, privileged driving in bus/taxi lanes etc.
However, in this project I will not go further into a discussion of car taxes and other things that could be done to get more electric cars on the road.
Another issue that could be problematized is that lithium is a limited raw material, and the production of the huge number of the batteries needed will put a pressure on the natural reserves of lithium. As a reaction to this issue, there is an interesting development going on with more sustainable and potentially even cheaper batteries of alternative materials.
Last but not least it could be very interesting to discuss how the development of selfdriving cars will affect the electric car and maybe also the connecting infrastructure? It seems inevitable that there will happen a lot within development of the selfdriving car in the near future, and it will maybe disrupt the way we use cars and change the need for cars and the consumer patterns around them.

The development of selfdriving cars could also lead to more sharing economy and challenge the traditional ownership model where everyone owns his or her own car.
However, in this master thesis I will not discuss these topics, but only concentrate on questions related to infrastructure for electric cars.

A brief historical introduction to the electric car

The electric car is actually a very old invention and was among the first cars that drove in the streets.
At the end of 1800 hundred all cars registered in New York were counted, and it was found that ther more a lot of electric cars among the cars in New York streets. At 1896 there were actually more electric driven cars then gasoline driven cars in New York – but most of the cars had a steam driven engine at that time. 1681 steam driven, 1575 electric and 986 was gasoline driven. (Elbiler.dk 2018)
But at 1912 the electric car was for real outcompeted when Cadillac invented the electric starter for combustion engines. The 1912 Cadillac Touring Edition was the first car in the world, equipped with both electric starter and lighting, that was called "delco system" and is basically similar to what we know today of a gasoline powered car.

The electric car was actually on the roads before the combustion engine. This model is called dodo and was one of the first electric cars. Source: Aboutelectriccars.blogspot.com, 2018

In early 1980s, there was renewed interest about the electric car as a reaction to the rise of oil prices.

Denmark was also present at the early development of electric cars with the development of a small car called CityEl (with nickname “Ellerten”). And with more than 500 sold cars, it actually became the bestselling electric car in the world at the time. But the company went bankrupt only one year after the car was put on the market.

Then several years passed without that much interest in the development of the electric car. A first breakthrough came in 2008 when Tesla launched the Tesla Roadster that created a lot of attention because it was the world’s first electric sports car.

At 2008 Tesla launched the worlds first electric sportscar. And put some hype into the car industry, and showed that the electric car also could be cool. Source: Road & Track, 2018

Infrastructure - Different standards in the market

Its obvious that when the electric car achieves widespread dissemination, there will be need of a good infrastructure.
There is a lot of actors that make bi investments in infrastructure. It the best of all worlds it will of course be best if all the car companies and other involved partners could agree on one common standard. But as always, the reality is no not that simple.
Therefore, this chapter will contain a description of the different standards of charting of electric cars. It will have a technical angle.

The battery in an electric car is charged using direct current (DC). Therefore, alternating current (AC) power supplied by the main grid must be rectified before it can be used for charging the battery.

This is done in the cargo unit built into the car. The efficiency of the charger determines how fast the car can be charged with AC and how much energy is lost during charging.

For example, the internal charger in a Nissan Leaf can only power up to 33 kW, while the Renault Zoe can add up to 43 kW. Tesla comes standard with an 11 kW internal charger, but can be extended to 22 kW (dual charger).

Fast charging usually takes place with DC, where the charging unit itself is outside the car. It is the charging station itself, which has the charger. This enables very high voltage (short charging time) and simplifies the design of the charger in the car, thus not having to handle the high voltage.

The disadvantage of placing the charging device in an external charging station is that it requires a significantly greater investment to install a DC charging station than setting up an AC charging box or an industrial plug for use with the charger in the car.

Installing a fast charging station with CHAdeMO (= CHArge de Move) and CCS (= Combined Charging System) or a Tesla Super Charger can cost more than hundred thousand DKK.
It means that is it very important what kind of investments that are made in the future.
In order to get an overview of the different standard in the market, I will describe them here, with a technical focus.

Type 1

Type 1 connector is common on Japanese cars and is standard in North America.
It is used to supply the car's singlephase AC charger. Type 1 connection is specified to handle 120 and 240 V, up to 80 A.

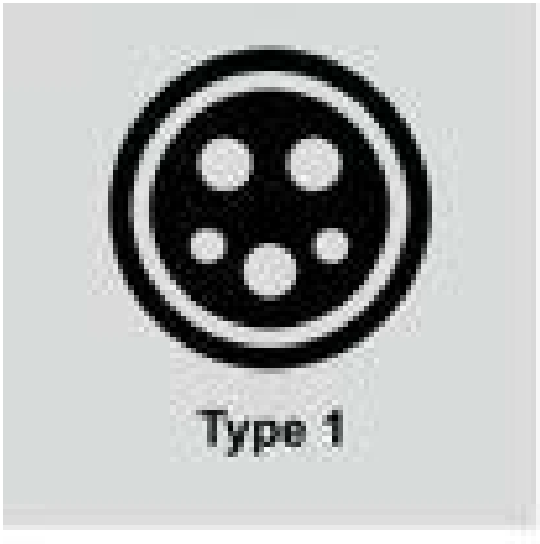
Type 1 supports effects up to 19 kW, but in practice it is only used for charging up to approx. 3.6 kW (230 V, 16 A). There is only support for singlephase power supply in a Type 1 connector.
It has five connections, two of which are charging current, one is ground, and two for signal transmission.

Security mechanisms
As long as there is contact via the signal connection, the car will not be able to start. The pilot signal ensures communication between the control box and the charger in the car.

The connector is designed in such a way that the connectors for signal transmission will lose the connector first if the plug is pulled out. Therefore, charging current will be disconnected before the switch is fully pulled out.
There is also a safety mechanism in the physical release mechanism in the plug which immediately breaks the signal connection and thus the charging current if the release mechanism is affected.

Type 1 connector can be used with a type 2 socket on a charging station using a cable that has type 1 connector on the vehicle side and type 2 connector on the power outlet side. (Adapter)

Type 1 connector is in practice only used in cars, which also have CHAdeMO connection for quick charging.
Type 1 is used in car models, such as Nissan Leaf, Nissan EV200, Peugeot / Citroën / Mitsubishi "Trips", Kia Soul EV, Ford Focus Electric.



Type 1 is round shaped and common on cars who also use CHAdeMO for fast charging.

Type 2

Type 2 connector is very flexible. It supports DC and AC, single-phase and three phase. Furthermore, it is relatively small in size.
The plug has seven connections. Three are three phase leaders, one is zero, and one is ground. The last two are used for communication between car and charging point when connecting to mode 2 or 3 at a charging point.
Type 2 connector is specified up to 500 V AC and 63 A, three phase, or 70 A, single-phase. Quick AC charging with Type 2 connector is in practice based on three phase alternating current.
The connector can also be used for DC, up to 500V and 140A, by using multiple phase connecters depending on the current.

No contact, no power

As the Type 1 connector, Type 2 is designed in such a way that the phase conductors are not tensioned before the control signals are in place. These are located deeper in the connector and will therefore be switched off first if the plug is pulled out.

Therefore, phase conductors will not be powered if the plug is pulled out. This avoids the formation of lighting and damage to the connector and plug.

Type 2 also has a mechanical lock, both on the car side and on the power outlet side, which is controlled by the car. This prevents you from removing the cable even if charging is complete. It also prevents the plug from being pulled out while it is powered. The car owner has to unlock it from the car.

It is not possible to put the car in motion while it is connected.

Many cars support the Type 2 connector, but not every car model can fast charge with it. In practice, only Renault Zoe, SMART and Tesla Model S are currently available, which can be fastloading or semifast-loading with Type 2.

Only one contact required

The advantage of Type 2 is that there is only one charging contact required. The contact itself is also relatively small and simple.

Public speed chargers using Type 2 usually deliver up to 400 V 63 A three phase AC. This gives an output of 43 kW. It requires that the charger in the car is able to handle such an effect.

Right now, only Renault Zoe has such a charger built into the car.

Practically all electric cars sold in Europe can use Type 2 for normal charging (2kW 11kW).

The CCS connector is based on type 2 connectors, and takes alternating current into the part of the connector that has the same shape as Type 2.

Type 2 is used by: All cars with CCS, MB BClass Electric Drive, Renault Zoe / Kangoo, Tesla Model S.

With the correct charging cable, Type 2 power outlets can also be used by all cars with Type 1 connector for singlephase charging. The Type 2 signal connection is compatible with Type 1.

Tesla's Type 2 version

The European version of Tesla Model S does not support fast charging with AC over Type 2, only semifast charging, up to 22 kW. Double charger in the car is required in order to achieve that effect.
Instead, Tesla uses a modified solution based on Type 2 connector, which can also receive DC power at 120 kW. Here there is support up to 500V 250A, which is possible at Tesla's Super Charger stations.
In this setup, all phase conductors are used for DC as is generally possible on Type 2. However, Tesla has amplified the Type 2 connectors enabling them to deliver much higher power levels.

It is not possible to charge other than Tesla electric cars at the Tesla Super Charger stations, despite the same design of the Type 2 connector. Communication between charging station and car will prevent charging from starting. Modified Type 2 is used as a result. (Steffensen, 2018)

Tesla has build up their own network based on the type 2 plug. Its reverse compatible, meaning that Tesladrivers can use other type 2 plugs, but other drivers can not use Tesla´s super charger network. Source: Toma 2008

CCS Combo

The CCS connector is a further development of the normal Type 2 connector, but with special contacts for DC. Grounding and communication take place through the contacts in the Type 2 section.
Combo (Combined) Charging System, or CCS as abbreviation, is a system developed in an attempt to harmonize charging worldwide. It is a further development of existing Type 1 and Type 2 contacts.
While Europe and China want to use threephase AC for charging, this is not prevalent in Japan and the United States. Therefore, CCS has been based on existing plugs, but added highpower DC power jacks.
These extra two connectors can deliver up to 500V 200 A, giving a power of 100 kW. In practice, 50 kW is supplied on public DC power stations today. (Steffensen, 2018)

Identical with Type 2

The CCS connector's upper part of the plug is completely identical to the regular Type 2 connector. For quick DC charging, the lower contacts are used. The Communication Plugs in Type 2 section are used for communication between car and charging station.
The contacts in the upper part of the Type 2 connector are used to connect the AC to the car when no need for fast charging. That means that only a standard Type 2 cable is required for normal charging of a car with CCS connector.

The security mechanisms at CSS combo are the same as for Type 2.
The advantage of CCS is that cars in theory can be built to support fast charging with both AC and DC. In practice, only DC is currently used for fast charging of cars with CCS.

CCS is used by all the European car brands a few examples of cars that is using CSS combo is VW eUP, VW eGolf, BMW i3. (Steffensen, 2018)

The CSS combo is used for fast charging. A Normal type 2 plug will fit above.

CHAdeMO

The CHAdeMO connector is used for fast charging of mainly Japanese cars. It has a comprehensive communication system with both analogue and digital signaling between the car and the charger.

CHAdeMO is a standard developed by mainly Japanese automakers and the Tokyo Electric Power Company. In this system, only DC is used. Therefore, cars using CHAdeMO must have a separate AC connector. Since CHAdeMO is only used by cars from Japanese and Korean manufacturers, Type 1 is used for this purpose. CHAdeMO operates up to 500 V, and can deliver up to 125 A. This gives a power of 62.5 kW. In practice, most CHAdeMO quick chargers deliver up to 50 kW. However, the CHAdeMO specifications allow current levels of up to 200 A in the future.

Redundant system

The security is of the CHAdeMO plug is that the connection is physically locked during charting. There is no tension on the connectors before the car “approve it”. If the monitor for ground faults during charging the charging will stop immediately.

The CHAdeMO connector has ten connections. Two of these are for DC, two are for communication with the vehicle's system, and the rest is for analogue communication. This is a redundant system. The analogue communication is used to send a signal indicating that charging will start. Information about battery capacity and charge current is then sent from the car to the charging station. If everything is in order, the car will allow charging to start via an analogue signal. Then plug the will lock into place into place and test for ground connection before charging starts.

If the analogue signal is interrupted, charging will stop immediately. It is not possible to put the car in motion while it is connected.

CSS and CHAdeMO has a different form and are not compatible with each other. Evan if there is a adapter available, it will not function although both CHAdeMO and CCS use DC, they are not compatible with each other. This is because they use different communication protocols between the car and the charging station. While CCS uses the GreenPHY protocol, CHAdeMO uses a proprietary protocol in addition to the CAN bus protocol. CHAdeMO is used by: Nissan Leaf, Nissan EV200, Kia Soul EV, Mitsubishi Peugeot Citroën. Peugeot Partner and Tesla Model S also support CHAdeMO through a special adapter. (Steffensen, 2018)

It’s obvious that CHAdeMO and CSS combo do not fit into each other. But even if someone developed an adapter, the two standards will not work together be course they use a different protocol for commination between car and charting station. Source: Greentransportation.info, 2018

Ordinary electrical contact

The vast majority of cars can be charged from a standard electrical outlet with ground. The advantage is availability almost everywhere, but there are many limitations on how much power that ca be delivered.
Most often, the limitation is 10 A (2.3 kW) and in many cases only max load is allowed for a limited period of time, for example not more than 3 hours. Particularly in old electrical installations, with many switching points between fuses and electrical outlets, it can be problematic to charge 1016 A over longer periods.

Overheating of cables and assembly points as well as the mains socket can be a serious problem. In old and faulty electrical installations, a fire hazard may occur.

Unless you can use a power outlet with direct cable lead to the power panel and with separate fuse, a standard power outlet should only be used for emergency charging over a shorter period of time. The current should be limited to 610 A.

The safest solution, which also provides shorter charging time, is, as previously mentioned, a special installation with a solid charger or industrial connector with sufficient current. (Steffensen, 2018)

All electric cars are able to use a ordinary plug at the house. The charting will happen very slowly and for security reasons it is not recommended at houses with old installations. Source: Ingeniøren, 2018

The current and futuristic networks in Europe

Tesla´s supercharger network

Tesla has its own supercharger network with 1,342 stations all over Europe. They can only be used by Tesla owners and not by other kinds of electric cars. (Tesla.com, 2018)

IONITY new fast charting network in Europe

IONITY is a network based on a European cooperation between several major car groups. Among the owners are BMW, Mercedes-Benz, Ford and VW with Audi and Porsche. Initially, a network of more than 400 is rolled out with 350 kW's DC chargers that using the CCS standard. The launch of the network has started with the first 20 locations in 2017 along the highways across Europe. In 2018 they are followed by 100 more and the rest in 2019.

CSS and CHAdeMO charting points in Europe

The CSS combo standard has 5195 fast charting points spread all over Europe. (Ccsmap.eu, 2018)
While CHAdeMO has 4000 charting points. (CHAdeMO Association, 2018)

Focus at fast charging

There is two modes of charging. Normal charging and fast charging. This Marter Thises will focus on fast charting, due to the argument that it is here there is most need of common infrastructure, because its what have to be alongside main roads.

Methodology

My empirical material consists of scientific articles and written articles from newspapers and magazines. The main source is interviews with experts and stakeholders around the subject of infrastructure for electric cars. As a part of the project I participated in the big political event Folkemødet to follow relevant debates around the topic, that was quite a hot topic at Folkemødet this year. Therefore, I also use Thick description as a method to construct my observational data.
In this part, I will describe the methods I have used, and explain in which way I made use of the methods more specifically.

Interviews

I have interviewed a variety of persons who are all either involved with – or have an interest in – infrastructure of electric cars. I have made 4 formal interviews and participated in 2 debates at Folkemødet.
The first formal interview was with Torben Arent, who is specialized in representing the electric car at car owners' interest organization FDM (Forenede Danske Motorejere). I got all answers to my questions I had prepared as a semistructured interview. I chose to transcribe all the interviews, to make it easier to analyze.
My next interview was with Lærke Fladder from Dansk Elbil Alliance, a lobby organization representing different stakeholders around electric cars. She made it clear that she only had 30 minutes before her next meeting; this meant that the interview was made in a high pace without too much time for an open dialogue, and deviation from the interview guide. Nevertheless, I got answers to all the questions I had prepared for the semistructured interview.
I also was lucky and got an interview with Maritn Messer one of the leading forces of FDEL (Forenede Danske Elbilister) who at the same time work as developer at the American techcompany called NUVEE). The

company develops technology that can stabilize the electric supplygrid by sending power back from the cars to the supplygrid.

On of my last interview I was lucky to have a very interesting conversation with Lars Sørensen a business developer from Clever. Clever is a company that develops and runs charging stations for electric cars in Denmark.
The company is 94 pct. owned by of one of the big electricity and energy supply companies, SEASNVE, that has sufficient capital, enabling Clever to make investments that are not economic beneficial right now, but is seen as a long term investment. In the financial year 2017 Clever made an operational loss of 17 million DKK.
Lars could put an interesting angle on my subject, because he has a big insight in which kinds of larger charging network that are about being established along European highways – the IONITY network described in the previous chapter. And beside of that he of course could tell a lot of Clever's business model and challenges for the future.

All my interviews have taken the form of a semistructured interviews, where I tried to understand themes from the daily life from the interviewee's own perspective. In practice it comes close to an everyday conversation but takes form as a kind of professional interview setting. It is neither an open everyday conversation nor a closed questionnaire. It is based on a prepared interview guide that focuses on particular issues of interest, and possible questions. (Kvale and Brinkmann, 2008)
When doing a semistructured interview, it is recommended to have issues and questions prepared, but in the conversation with the informant, the questions and issues can evolve depending on the answers you get. The strength of a semistructured interview thus lies in its ability to be an informative conversation with the ability to produce new insights that were otherwise not clear beforehand to the interviewer. (Kvale and Brinkmann, 2008)

Transcription

I transcribed all interviews I have conducted, in order to get the most precise data for the analyze. When transcribing interviews, it is necessary to choose the most appropriate method to do so. This could seem to be nothing but a straightforward task of just writing down what was said at the interview, but it actually involves a bit more than that. From the beginning I had to figure out what level of detail to choose from the interview. Due to the fact that it was only expert interviews and the fact that there would be no analytical points of including exclamations such as “uhh”, “ahh” etc., and the way the informant put pressure on some words, I chose to omit those details in my transcription. Neither did I include details such as nonverbal dimensions of interaction during the interview. Had it for example been an interview on some private or more sensitive issues, it could have been relevant to include details about how words are said by the informant, or to notice the body language he/she makes when talking about certain things.

At the same time, it is also a question of finding the most appropriate way of representing the expert informants, which is by transcribing in a fluent written language that makes sense and is clear compared to the topic.

All my interviews were conducted in Danish, since all informants were Danes. Therefore, I transcribed the interviews in Danish, mainly to avoid any misunderstandings from a potential translation from Danish to English. However, the quotes I use in the analysis, is of course all translated with great care, to avoid any kind of misunderstandings or misinterpretations during the translation.

Thick description

Thick description is used to explain and describe the field we observe. Clifford Geertz, known as the originator of thick descriptions, claims that an anthropologist's task is to explain an incident, event, environment or culture through thick descriptions. This method specifies many details, conceptual structures and meanings. A contrast to thick description is thin description, which is a method of facts without deeper reflection and explanations (Geertz, 1973). Thin description, according to Geertz, is inadequate when studying a phenomenon and it is also misleading. An ethnographer must present thick descriptions, consisting not only of facts, but also of descriptions and interpretations, as well as reflections on the comments and interpretations you do. These are some of the important criteria to an adequate thick description. By this is meant that a phenomenon should be an interpretive practice that tracks the way the meaning is ascribed. The raw observational material collected by an ethnographer is not sufficient if we are to make a thick description of a phenomenon. Hence, the social discourse is an important factor in the interpretation, and one has to take into account extroverted expressions as well. Data collection and interpretation are therefore limited to what the informants can tell us (Geertz, 1973).

Theory

As a theory for this project, I have chosen to use Actor Network Theory (ANT), because my focus is how the different actors that are related to charging of electric cars shape their network and what kind of alliances that are created.

Actor Network Theory

The frame that ANT offers is good for studying subjects where there are more than just people involved and therefore cannot only be considered as a social phenomenon or construction. In the analysis, human and nonhuman subjects are treated equally, and it is assumed that they both can affect each other equally in the network they form. It could for example be one or two certain connectors that already is produced and on the market. That will for example challenge or interfere with a humanbased decision of either to change it or to make only one standard.

When using ANT as an analyzing method, one of the most central concepts is that human and nonhuman actors can be equally important for the analysis. At the same time, an important point is that actors never act on their own, but always act in a network. Each player can only achieve its effect through the network it is part of and can only occur based on the relationships the player has in the network. It is precisely how the conceptual player network should be understood. (Järvinen and Mik-Meyer, 2017, p. 371)

Nonhuman actors can be many different things, including any kind of objects, technologies, documents etc., but it may also be other biological material such as animals or plants. One of the other key points within ANT is that the subjects studied in social science research are often characterized by the social acting between humans and therefore mostly involve social phenomena, so it is very important in this case to involve or include a technology on an equal level with the human actors. Latour

defines an actor as "anything that modifies the state of things by making a difference" (Järvinen and MikMeyer, 2017, p. 370). That means that an invisible actor who leaves no trace or forms part of anyone's redeployment cannot be classified as an actor. At other words it menas that an actor have to leave a visible trace at the network in order to cunt at an analyze.
You cannot divide ANT's network between human and nonhuman actors and try to establish two “kinds of network”: one with human actors and one with nonhuman actors. Furthermore, you cannot split the network for example between exclusively social actors or exclusively technical actors. There are always heterogeneous networks that consist of both human and nonhuman actors. (Järvinen and MikMeyer, 2017, p. 375)

Black box

ANT operates with a central feature called black box. The black box can be compared to the central control unit in a factory production. It is the unit that controlling it all and as long as it works, there is no one who thinks about it, but if something breaks down, many people suddenly begin to be interested in its function and maybe start asking critical questions.
You can also say that a black box is characterized by its stable and uncontroversial functioning and it is always taken for granted in the context of which it is a part of. Therefore, in ANT, it becomes an important point to study any kind of process, that leads to a temporary order. At ANT any form of structure and order is seen a temporary, and the actors with for example money, technical artefacts or lawmaking trys to influence and challenge existing positions.

Latour formulates the effect of blackboxing, saying “you no longer care about the complexity of the process inside the box but focus more on input and output”. (Latour, 2000 p. 32)

Translation

In order to analyze such processes, Latour and Callon use the analytical concept of translation.
Translation refers to creating relationships and similarities between elements that are not in themselves similar to each other. It is important to investigate how relationships between different actors are created so that it appears as a coherent order. Here it is worth noting that they create relationships neither social nor natural, and that they could be established elsewhere. An important point is also that actors change when they engage in translation processes. Translation therefore always contains transformation that is mutual. This means that the actor forms of the network and the network forms the actor. And one actor never act alone, but always in collaboration with eacth other (Järvinen nd MikMeyer, 2017, p. 377)
Translation is also about power of balance, which is explained by the fact that each actor is struggling to create a good network.
In the analysis, when working with ANT, one should endeavor to use that same concept of language, whether you talk about a human or a nonhuman actor.
In ANT, there is always an underlying premise that change is the basic condition and any form of stability is considered to be a temporary condition that requires an explanation.
A question could be: How do you choose the right actors for the analysis? According to Latour, there is no clear answer to it, and the closest Latour comes to an answer is that it is a contingent choice – it means that the selection could always have been different. (Järvinen and MikMeyer, 2017, p. 379)
I will through the analyses try to use an ANT angel, at the information that I got from my informants and in general treat the subject using the ANT understanding.

The case of the electric vehicle

Callon has written some interesting points and perspectives on how ANT can be used.
Callon use an older real example of an attempt of creating an electric car in France in the early 1970's.
It began with an ambition within the French Government of launging an electric car.
The national utility Électricité de France presented a plan for the electric car that involved of lot of different actors. The company "General Electric" should develop the engine and the battery for the car. The well-known car company Renault should produce the chassis and the car body, which does not differ much from classic car production. The ministry of Transportation is a part of the network as well, and it was planned that they should formulate a supportive and positive politics about the electric car. (Callon, 2018)

Callon describes how a whole actor world was built up around the car from Électricité de France. But at the end Renault withdraw from the project and thus showed how fragile an actor world could be. The other actors in the network was totally dependent from Renault who should produce the body and the chassis, and could not lift the task of producing a electric car alone. The actor world fell apart. (Callon, 2018)

In other words, an actor world was built up, an academic term Callon uses to describe a vision of the future. The term can also be qualified with ANT terms. Callon believed that an actor world should be a future vision, that consists of technical components as well as a plan of the actors that should be in network. Furthermore, the actors are dependent from each other. This point is clearly demonstrated by the fact that if one of the actors leave, the whole actor world would break down, as Callon showed with Renault.

Callon also introduced the term “translater-spokesman” that can be defined as the central unit in the network. It is the actor that holds the vision, and if other actors are enrolled in the network, the translator-spokesman, will express the vision on their behalf.
At the case described above Électricité de France for example becomes a spokesman of Renault. Renault is no longer spokesman for the cars they produce, but it is Électricité de France that uses Renault as a production facility. It was also one of the reasons that Renault withdrew from the electric car project in 1970. They did no longer hold the vision of the things they produce, because Èlectricité de France holds the electric car in their role as translator-spokesman.
In the analysis I will bring in the ANT terms that Callon uses in the “The case of the electric vehicle”

Analysis

In this analysis I will start by describing an ambitious infrastructure project that end up failing. Then a short introduduktion to the different standards in the market.
Then I will look at Tesla´s own network and describe their vision of a closed actor world.
Then I will look at the technical advantage and disadvantage on CHAdeMO and CSS combo, followed by a explanation of the big prestige charging project in EU, IONITY.
Then I will look at the potential of translating the electric car into the power grid, and helping balance the network with power – when the energy level is low, the network can use power from car battery's.
This concept is then described with help of a mini case from Roskilde festival. Followed by an ANT reflection on how it could work on a society level.
Then the last part of the analysis will reflect on my sub quistion about payment.

Better place – an example of an actor world that failed

Better place was launched at October 2007, as Project Better Place, by Shai Agassi, the company's founder and CEO at the time.
Better Place was a good example on how an actor world is build up. It contains a vision and several technical actors working together.
Better Place believed that they had the solution of the future infrastructure. Better Place's solution was to fix the problem that electric cars have to wait for a longer time than gasoline/diesel cars while filling up/ charging along the highways.
Better Place developed battery stations, where the battery was physically changed to a new one within 1-2 minutes. (Fast Company, 2018)
The change happened automatically. As a driver you just had to drive your car over a marked area in one of Better Place's charging stations

and then an automatic robot system removed the battery and replaced it with a fully charged battery.
With that system Better Place defined the owner structure in two ways. The costumer owns the car as usual. But Better Place owns the battery(s).
Better place also provided the costumer with a home charger.
The customers were offered a choice of five fixed-price switchable-battery packages based on kilometers driven per year.
In order to make the switch technically possible Better Place had to build an actor world that also included cars that were able to support the function of a changeable battery. It had to be specific designed to fit Better Place's systems which means it cannot fit any other system.
Therefore, Better Place had to enroll Renault in their actor world in order to let them make a car, that fit exactly into their systems.
Renault Fluence Z.E. would be the first electric car with a switchable battery available on Better Place's network of battery swap charging stations. (FDM, 2018)
By then Better Place also became a translator-spokesman for Renault Fluence Z.E. model, that was mostly known as the "Better Place" car.
But in 2013 the whole actor world around Better Place break down, because there were not enough costumers compared to the investments that Better Place had made in the battery changing stations. Better Place went bankrupt. (Fast Company, 2018)
The reason for that was of course that Better Place was outcompeted by newer and better technology. There are nowadays an increasing number of electric car models on the market and for most costumers it is not seen as a problem as such to own an electric car – and when you own your car, you do not want to be dependent on one specific company when it comes to a central unit as the battery.

In addition the general development in batteries and supercharging has made Better Place way to do it redundant.

The example shows how easy a complex actor world can fall apart, if just one element does not make sense anymore.
This was just a brief historical introduction to one of the first Danish attempts to create an infrastructure for electric cars. Today all the 17 Better Place battery switch stations in Denmark are abandoned.
There are still around 500 Renault Fluence Z.E cars left in Denmark, and they are not that much worth without their network. They can still be charged with an average plug from the house, but the function that the battery is changeable is useless.

The situation today is different. Now all the cars on the market have a fixed battery and the development of batteries as well as fast charging is moving fast.
But what about the standards that we use for connection between the car and the charger? Which standard is the smartest one and which kind of networks are created around the different standards?

Different standards in the market

Based on empirical material, I can see that there is currently a “format war” with Japanese CHAdeMO on one side and the European CSS Combo on the other side. To get started I will describe some of the objective technical advantages and disadvantages with both types of plugs. CHAdeMO has a clear technical advantage that power is able to run both ways. The car is then able to return power back to the supply network. CHAdeMO was a first mower and that means that cars with this type of plug can only charge up to 50 kW.

This central feature is not available with the European CSS Combo standard, which, on the other hand, has the great advantage that it at its present stage can charge with an effect of up to 350 kW. This means significantly faster charging, which again means that the user can get his or her electric car faster on the road again, when they drive long distance. The interviews I conducted as well as the debates I participated in had a strong focus on the need for collaboration between certain actors and as some of the most important I have tried to clarify who already works together with whom and to look at which networks and collaborations that are or will be established when it comes to the overall infrastructure in Denmark and Europe.

In addition, it also appeared that payment for charging outside Denmark was also a point where the electric car owners experience difficulties due to the lack of common standards. It turns out that all the companies working with charging, has their own card or chip, an often where the costumers need a subscription (VISA/Mastercard payment is not an option) Therefore, the payment for charging the electric car will also be talking to constitution during the analysis.

In the beginning of the analysis, I start asking what the various actors in the electric vehicles charging network expect a massive distribution of electric cars.

There is definitely some ketchup effect involved. The curve has not risen particularly much yet that is, except in Norway, where a lot of things are happening. There will happen a lot here in Denmark in the next two years, I think. Most of the wellknown car brands will introduce new electric models to the market; models that are also smarter than they are today, they have a longer range and the price is also slightly falling. Hence within the next 12 years I think there will happen a lot with the electric car.
The established car manufacturers believe that by 2023, 25 per cent of the carpark will consist of electric cars. This number can sound small for some, but when one thinks of how huge the industry to be changed is, how much infrastructure that needs to be rolled out, habits to be changed etc. – 25% is definitely a lot.
Torben Arent, FDM

There are many indications from the big analyzeinstitutes that something really happens from 202021 where the electric car will hit the masses. At that time, all the experts and investment banks have an expectation that there is a price alignment between the conventional car and the electric car.
Lars Sørensen, Clever

Thus, there is a widespread consensus among actors working in the field, analysts and the car industry that after 2020 the electric cars are in fact a major part of the total car fleet. Therefore, the decisions and investments made now, are very crucial for how easy and attractive it will be to drive electric cars after 2020.
Furthermore, the development seems to hit the market with some "ketchup effect" which can affect the appetite on investment as well as the appetite from consumers to buy electric cars. Mainly be course costumer will get the full advantage of the technology, when all the investment in for example infrastructure. But many actors wait with doing investment before there is a secure market.

Today, the total number of electric car sales are only around 2 per cent of the total car sale in Denmark. We come from a situation where electric car sales were down below 1 per cent of the total new car sales in 2017, and now, at April (2018 red.), we are at around 2 per cent of total car sales. So, we are experiencing a great interest in electric cars at the moment, but we also come from a quite low level.
Lærke Fladder, Dansk Elbil Alliance

This is how the framework looks like that the different actors in the field of charging must operate within. By the nature of the matter, it is always difficult to predict the future and therefore, I will not relate to exact numbers. However, this master thesis is of course based on the same reality that actors in the electric car industry have to deal with. The companies that deal with charging and infrastructure for electric cars, also have to make decisions that reach into the future, based on the knowledge that is available today.
In other words, this thesis is not a discussion on what will happen in different hypothetical scenarios, but of course it reaches into and discusses elements in a unknown future.

It is clear that we need a completely different infrastructure than the one we have today. If we just assume 25 per cent of the car park there really must be a lot of charging possibilities, especially in the urban areas. On the highways, we are doing quite well with fast loading stations etc. You are reasonably comfortable with driving between the different parts of the country being able to charge 50 kilowatts or more.
Torben Arent, FDM

In this analysis, I will assume that at least 25 per cent of the car fleet will be electric after 2020. Perhaps it will even be more. But all the things I touch upon in the analysis also have relevance s today.

A considerable number of charging stations has been rolled out in Denmark and rest of Europe and as mentioned in the introduction there is a slightly higher number of charging stations already today, compared to the number of gas stations.

In this master thesis, I will as a principal rule take conditions for Danish car drivers as a starting point and show many examples from Denmark. With this I mean that in the master thesis and not least in interviews and data collection the primarily focus is on Danish conditions. However, Danish drivers are also driving outside the country's borders. Or, at least, they want the opportunity to do so, and it is an important parameter when buying a car. Therefore, I also look very much at the cooperation between and with foreign stakeholders regarding infrastructure for electric cars. The different types of plugs that are on the market is the same all around the globe, but especially the issue of payment which is addressed by the end of the thesis, makes it important also to have a focus outside the boarders of Denmark.
In North America, Type 1 (rather than Type 2) is often used by the CSS combo plug. This fact is not handled in this thesis, but it may be relevant for the reader to notice.

(…)and this also applies when driving around Europe, I cannot drive up to my country house in Sweden, because Sweden does not have a particularly good infrastructure as we know it in Denmark so far. Particularly on European level, there are some collaborators on their way in the future.
Torben Arent, FDM

As Torben mentions here, it is clear that the vast majority of electric car owners regularly need to be able to drive outside the country's borders. It is therefore important that as many drivers as possible get involved in the network, so the market can provide a better infrastructure where the

electric car owners do not have to worry about charging options, regardless where they drive. Right now, it is only a small passionate group that are inside the network. The majority of car owners will be outside of the electric car's network.

These first movers are making a virtue of planning the trip, driving as far as possible on a charge, etc. However, this does not apply to the vast majority of drivers where the car mostly is about freedom and convenience. And then the electric car comes and then we suddenly have to think and worry about it while we drive. It can be done, but the driver needs to think carefully about it and plan the trip. Someone says that it is an advantage I you'll never have to go to the gas station anymore, but I'm filling my diesel car once every 3 weeks. 4 minutes every 3 weeks and I do not even think about it.
Torben Arent, FDM

Format War

As it is today, there are generally 3 different standards in the market, and each one is surrounded by their own network of actors.
In this section of the analysis, I want to get an overview of which networking configurations of actors we see around the different standards that are currently involved in what we use to call a format war a bit like we saw on the video market with VHS and Betamax in the late 1980s. At that time, many experts believed that Sony's Betamax had the best technology, while another Japanese company, JVC with their VHS video format, won the format war mainly due to a lot better marketing strategy, and therefore got better grip at the customers. German Grundig and Dutch Philips were also involved in the format war with their Video 2000 but draw back from the market in 1988. VHS triumphed at the end of the 1980s and dominated the home video market until 1996 when the DVD format was released.

Similarly, we are also in the middle of a war of technology about the charging of electric cars. Because we are "right in the middle of it" it is difficult to determine which standard is objectively best or technologically has most advantage. It is also an element that in particular make this master thesis a challenge. That we are in the middle of an technologically, development trying to look into the future. I would be easier to make analyses, after one of the two actors has won the format war.

Tesla's own network

The first charging standard service I want to describe is Tesla's own. Tesla is a very special case, as it has its own standard, but on the other hand Tesla owners are able use the network public chargers (except CHAdeMO quick chargers, that require a transformer that Tesla also has developed)
It does not count the other way round, so none of the other car brands are able to use Tesla´s super chargers.
The Tesla network counts specifically 1,317 charging stations with 10,738 Super chargers. These charging stations can as mentioned above only be used exclusively by Tesla cars. As Tesla is considered to be a first mover on the electric car market, a lot of hype was created around the car, which still lasts on even if there is now many competitors. Tesla is generally a much more closed network than the other standards, because it closes around itself, and right now does not have any interest in getting any other actors into the network.
Tesla creates their own actor world with own values that point towards self-sufficiency as an ideal. Until now Tesla also had the financial muscles to finance it, so they don need to enrollee that many actors into their actor world that we see in Callons example with Renault. Teslas actor world consist of Tesla solar panels on the roof, which then will be stored in the Tesla's Powerwall and/or loaded into the Tesla car's large battery.

In addition, the Tesla owners can charge free power on their own super-charger network. (The offer with free power when you buy a Tesla have recently changed, new Tesla customers should pay a small amount for the power they use) But it still a exclusive charting network only for Tesla drivers.
Tesla is different than the other two networks because Tesla has chosen to close the network around themselves.

Tesla has taken a big bite of the market and has very satisfied customers. I think that Tesla has done very well. They have taken the step forward reasoning that they will never be able to sell their cars if they do not fight the range fear. Therefore, it is a smart commercial gimmick with free charging, which they, however, have stopped now. You have got a car and you know where to charge and there is obviously a prestige in it. Mercedes, BMW and Audi are nervous because Tesla has entered their market so now they must do something!
Lars, Clever

The question is how Tesla handles the future if you focused at the super-charger network. Do they maybe want to open up and by then involve more actors in their network? Right now, there is nothing that points in that direction, but they have closed down the free charging, so that their new Tesla customers cannot get free power anymore.

Tesla is good at making cars, they are okay to charge, but they also see that when more and more Teslas are coming on the road, there will be more charging out there and it has a price. One KWh costs two DKK and a Tesla can quickly take 70KWh so it costs money every time and they are under pressure regarding their liquidity and they put a cap on how much you are able to charge. The 'popular' Tesla (Tesla model 3 red), which is now on the market, does not come with charging included. Tesla

is also affected by the economic reality because they cannot just provide free power, but it is smartly thought.
Lars, Clever

So maybe there is a slight opening if Tesla wants to make more money and generally wants to contribute to a better network for electric cars. The latter is mostly speculation for the moment and therefore does not constitute a real focus in this master thesis.
Instead, I will conclude that Tesla has its own wellfunctioning, but closed network in relation to the charging of electric cars.
In the rest of the analyses I will focus on the format war between Japanese CHAdeMO and the European CSS combo standard.

CHAdeMO

The second standard I will describe is the Japanese plug standard CHAdeMO. If we look technical at CHAdeMO, it has the advantage of recharging and thereby able to return power back to the electric grid. The Japanese were first movers on fast charging and CHAdeMO can charge up to 50 kWh, which was fast when the plug was launched in 2010. That was a lot of power at that time.
Toyota, Nissan, Mitsubishi and Fuji Heavy Industries (Subaru) have joined the Tokyo Electric Power Co to create a working group that have set the standards for fast chargers in Japan and aim for a global standard. Other 158 companies and public authorities including the French car manufacturer Peugeot-Citroen PSA are expected to join the group based on the CHAdeMO standard. The goal is to ensure chargers and electric cars share a common "language", thus allowing the charging system to work with all future electric vehicles.

CSS combo

The third major standard is the European CSS combo, that has the most European car brands – those producing electric cars behind it. In addition, it is also the standard that the EU parliament backs up. CSS cannot, in its current form, provide power back to the grid like the Japanese CHAdeMO can do. On the other hand, they can charge significantly faster, up to 350 kWh. As described above CHAdeMO can go up to 50 kWh. There is now a lot of disagreement and competition between the car manufacturers about which of the two different types of standard to use and invest in when new infrastructure is build. They are both in the market right now and many of the charging stations allow customers to choose between 2 kinds of plugs (comparable to a gas and diesel pump).
This has resulted in the charging cooperation IONITY, who held the ambition of building ultrafast charging stations all around Europe. At this collaboration the CHAdeMO plug is frozen out.

German car manufacturers have been very hesitant to agree on a charging standard for electric cars. They talked a long time about working together (....) That's why the Germans have finally got together and joined forces to make a charger that is very similar to Tesla's. It is currently being rolled out and is called IONITY. They will also have more chargers up to 360 kWh there will soon be a Porsche that can charge that fast. It will be a network that looks like Tesla the difference is just that everyone can use it. Everyone who has the European CCS combo plug. But anyone who has the Japanese CHAdeMO cannot use the network so it makes the Germans "put a spoke in Japanese's' wheel".
Martin Messer Thomson, FDEL

What we (Clever red.) have said in relation to these ultrafast stations, of which we build 48 in Scandinavia – at a price of 5 million DKK per station is that we install CCS. We want to be good friends with the car brands. Hence we have asked Nissan if they want to coinvest so the costumers also can charge CHAdeMO? They have said that they do not want to be in this network.
Should we bet on everyone or should we bet on one that we select? And there is also a tendency towards 'who's blinking first'. Because if we just do it for Nissan, we may overinvest. The EU says we have to offer CCS, so we do of course. The discussion on standards plays a role, but it is not the main barrier.
Lars Sørensen, Clever

In relation to the ANT perspective, it is clear how important it is to have an actor within the network, which itself has one of the largest possible networks in other contexts. The EU as an actor is a major advantage for a smaller network as it is able to affect most other players both inside and outside the charging network.
Despite that EU also is model if for example other part of the world will have a great charger network, they will properly look towards European union.

IONITY
IONITY is a joint venture of the BMW Group, Daimler AG, Ford Motor Company and the Volkswagen Group including Audi and Porsche.
IONITY is a network of reliable and powerful charging stations along major routes across Europe. The stations will have an exclusive design and are designed by architects and allow fast charging times due to the capacity of up to 350 kW. By 2020, IONITY will be operating more than 400 fast charging stations in 24 European countries. (Ionity.eu, 2018)
It is very similar to Tesla's charging network and will have the European plug as a charging standard. As mentioned above it will not be possible

to include the Japanese CHAdeMO plug on any of the IONITY charging stations

One of the biggest prestige projects in the field of electric car charging does not have the Japanese CHAdeMO plug as an option. What is the reason for Nissan not to join the network? It's a little paradoxical when Nissan sells far more cars in Europe than the total number of competitors do currently.

What speaks for CHAdeMO is that Nissan, which is the most sold and popular car, uses that plug. Tesla is popular but is also reasonably expensive. Nissan makes it outstanding and has been firstmovers and the existing customers are happy.
Martin Messer Thomsen, FDEL

So even when Nissan maybe has a bigger network in numbers of sold cars, the actors around CSS combo form a stronger network – at least here in Europe.

(…)on the mobile phone, you know that you need a specific plug to make it work. It has become a problem for us from a charging point of view and we could also wish that the state would step in. The car manufacturers have always done the same, but now they need to figure out how to charge the electric cars. Nissan has their charging point in front of the car, the Germans have it behind, Tesla has it on the left side. (....) If we do not agree on how we make this ecosystem, nothing will be done. I think and hope that CCS will be applicable in Europe, Type 1 in the United States and CHAdeMO in Asia. But if Nissan keeps investing in the Asian standard, not wanting to go away from their own CHAdeMO, and sends their cars into Europe, they'll also find out how to charge them, otherwise they will not be able to sell the cars.
Lars Sørensen, Clever

Maybe is the goal for global common standard too far away, and the different standards will dominate their own region. But Europe seems like an attractive market, therefore the format war is still on in the European countries.

New actor in the power supply network?

With CHAdeMO's new opportunity to reenergize the power grid, the power grid becomes a very important player in the network with the electric car's propagation. With a translation process, electric cars can thus be a very important player in balancing the electricity grid far better than we see it today.
As it is today, the power supply is dimensioned to what we call the peak of power, at around 1617 o´clock, when everyone comes home from work and start the stove, oven, washing machine and other electric devices. It requires high supply security and the power must be produced somewhere. Many power plants today do not produce the energy in a sustainable way.
If many electric cars are connected with CHAdeMO to the electricity supply network, it will be possible to balance the network much better so that the electric cars act as an additional generator that charges battery when the need of power supply is high, but the can supply the powergrid when the pressure is high, as it was described at the peak of power at the hours when people come home from work.

Test at Roskilde Festival in small-scale

At the Roskilde festival, an attempt has been made in a small-scale format, to stimulate the potential it could have to get the electric car with CHAdeMO standard enrolled at the power supply network.
Central to the festival square there is a large food hall where festival guests can buy food from a wide variety of food shops. In recent past years it has been running on the power from a large diesel generator that supply power to the entire food hall. The reason for that solution, is not

to put too much pressure on the general network that supplies the whole festival (Overcast.fm, 2018)

But this year (2018) the food hall was powered from the main supply. But as an important point, there is a limit to how much power they may use as the rest of the festival also uses power. Therefore, some students from Denmark Technical University (DTU) made a test and borrowed 3 Nissan Leaf cars with CHAdeMO plugs that is connect to the same electricity radial network as the food halls uses. When there is overload on the network, the cars supply the network with power, and when there is sufficient capacity on the network the cars get charged and fill up the batteries as usual. By doing that, the cars become an important black boxed actor at the electric supply network and also had a black box function to keep the power supply stable by ensuring that the peak load newer puts pressure on the main supply. The professionals called that phenomenon peak shaving. With the conclusions from the students from DTU who conducted the experiment, peak shaving is seen as the key to leveling the consumption, thereby reducing the maximum consumption of electricity. (Overcast.fm, 2018)
Several of my informants think that the electric car can play a role in helping to balance the power grid and thus have great potential at a large community scale.

The potential of translating the electric car into the power supply

You can actually help the electric network keeping up the frequency and balancing the network. In this scenario, the electric car will play a major role, because it can contribute to the power of the network – for which the user receives payment. The future power grid is probably a bit more unstable, because of the sun and wind, emerges as an energy source. Here the electric cars can play a big role.
Torben Arent, FDM

Torben points on the fact that many of the players in the electricity network are slowly replaced. At the same time as energy production becomes more sustainable with solar and wind, it also results in a slightly greater instability and an increased need for peak shaving, where the electric car could play an important role.
It also shows point from ANT that an actor never acts on his own but always in a network.
In this example, the need for peak shaving would have been less if the actors in the network of energy generating units had not changed. Because the energy level is high and stabile today with the actors who are in it now. But when energy production changes, there is an increased need for the electric car to contribute to peak shaving in order to balance the network around the power grid.
But what do the electric car owners get out of this new system? Nissan has suggested a model where the car owners get a small compensation in terms of money, for the service of putting power back at the power grid.

(...) by first and foremost charging when the power is cheap at night. And in addition, you can get a small reward to put your battery at the disposal of the power company to maintain some stability in the network. By making your battery available at the for the power grid. Some say that you can drive for free that way.
Torben Arent FDM

First of all, this ensures that the electric car owner has the right motivation to help the power grid if there is a need for extra power – particularly in the hours where the power peaks, when everyone comes home from work and turn on their electric devices at home. Secondly, as an electric car owner, you can charge your car when the power is cheapest at night and possibly give power back when it has the highest price. An average car stands still for 90 pct. of the time – and is only on the road for 10 pct. It means the chance is high for letting your battery in the electric car earn some money for you.

The power grid is designed for the "cooking peak" of power (5 o'clock p.m.) – plus a little extra. But there is good capacity for the rest of the day, so if the electric cars can charge smart, there is room for every household on the same radial to have 1.3 electric car on the average. Unless you want to build a new and enlarged power grid, it becomes crucial that you charge intelligently.
Lærke Fladder, Dansk Elbil Alliance

Most of the underground supply cables (called radials) at the villa roads were dimensioned back in the 1960s. This is one of the main reasons why there is limited capacity in the grid in the residential neighborhoods.

A survey that was conducted from Dansk Energy, showed that in such a common residential area, where the cables may be dimensioned back in the 60s, it was concluded that 3 electric cars (on a common road, out of a 30 35 houses) can charge on the same radial as it is called. It is while all other power is running at the highest level at 5 o'clock at the "cooking peak".
Lærke Fladder, Dansk Elbil Aliance

Obviously, it is therefore smart to use the battery capacity of the electric cars to balance the network. If the electric car becomes the norm, the alternative to smart charging will be to dig new and more powerful radials, which will be extremely costly.

If, on the other hand, you could do some intelligent management, so you come home at 17 h, plug in but it does not charge yet. Then it begins to charge when the network has high capacity again, meaning when the remaining consumption is at a lower level.
Lærke Fladder, Dansk Elbil Aliance

There is a lot of good arguments here indicating that the electric car can take a very central role in the new network around the grid. The electric car can potentially fill out a role that normally has been black boxed. Stability in the network is something everyone took for granted once there always was energy enough, almost whatever we connect to our electricity network.

The CHAdeMO standard therefore has the potential to create an actor world that is not closed around itself, but there is also a translation that involves the entire number of players within the general supply network. It is smart that the electric car thus helps to solve the challenge it creates when electric cars are becoming more and more popular.

Translation can be largely defined as a process that creates a connection between two different elements that do not directly interact with each other. CHAdeMO turns into a translator spokesman for the different power companies (depending on the areas they are in) by holding the vision of creating a stable network where everyone can charge their electric car without having to upgrade the whole infrastructure. The CHAdeMO standard has the possibility to spearhead something as simple as security of supply that has previously been black boxed. CHAdeMO is apparently the actor in charge of the actor world regarding charging of electric cars. If the electric car is becoming a key player in balancing the network.

A public or private task?

Is there any perspective of getting the public sector as an actor in the charging network?
The United Kingdom is just about to adopt a new law, which dictates that there must be an outlet for charging electric cars in all new buildings. Just as we also must make sure there is a power plug for e.g. washing machine and internet connection in new buildings.

Such a proposal gives an indication of how important an actor the state may be within such a network. The state can easily make things happen, but it is important that it is the right types of plugs that are installed. In England its of course a matter of who wins the format war. And so far, the proposal is just to ensure that connection is a possibility.
In addition, the United Kingdom Government also proposes that all streetlamps (at places where cars can park, mostly in the cities) are equipped with a charging plug or connectivity for charging. In particular, the proposal is for the people who today fail to switch from their conventional car because they live in apartments and therefore find it difficult to find chargers. (Gram, 2018)

In Denmark, the government is barely so ambitious in the electric field. However, the electric car business has got some public help to get started especially from the European Union. It is hard to imagine it can be completely private, at least in the beginning many believed it needed public support.

(...) yes, there have been some support programs (from EU ed.), I do not know about anyone right now, but there have been something for both hydrogen, gas and electric cars.
Among other things most hydrogen stations are all built, with support from an EU pool scheme. I also think that what E.ON and Clever have made along the highways have got a bit of EU money. So the charging stations are privately run, but there's some public startup help.
Torben Arent, FDM

The example shows how important it is to enroll the state or European Union and have them in the network, even if it is primarily at the beginning of the process.

We also know it from the phone where there has been a lot of plug and now it is almost standardized. And now it is almost the case with electric cars too. Let's just keep Tesla out, they have chosen a completely different model, I cannot judge if it will last forever. So at least, many cars are sold, they are expensive to keep up and running. But they are actually reversed compatible, so Tesla can easily be added to other networks, others just cannot use Tesla's chargers. And Tesla must decide for themselves, it is their decision to join a common solution or not.
Torben Arent, FDM

It seams like the national states has a big role to play in order make investments in infrastructure, and the European union has a big role to play regarding standardization.

Payment

As a bit surprising element that I was not directly prepared for before I interviewed my informants the payment issue showed up as a lack of standard which might be a serious problem for the electric car costumer – especially when driving long distances or crossing borders.
Basically, it is a bit the same problem as the different plug standards. Right now, there are many different standards and the different companies all have their own way of doing payment for charging, some has a subscription scheme, some have a chip and some have their own card. First and foremost, it is important to mention that virtually no one uses Dankort, VISA or Mastercard as a payment option. We are used to that you can pay with cards all over Europe, when you drive a gasoline car.

In Denmark itself the problem is not that big, but many electric car drivers chose to have subscription from E.ON as well as from Clever. But many drivers also move around and drive outside the country's borders – or at least have the possibility to do so. The problem with payment will therefore have a European focus in this master thesis.

It may be a bit of an obstacle because all the charging firms) have their own systems. So obviously some standardization is needed between operator and also country to country. You do not want to go somewhere and then you cannot pay because they use their own system.
Torben Arent, FDM

This indicates that a large number of smaller actor worlds are being created on the payment side, all of which try close around themselves.
As mentioned, it can be said that it is the same problem as with the plug standardization. However, the difference is that the difference in the standard itself is not as strong, as it can easily be simplified by programming, for example. That does not count for the plug issue, as the plugs per definition are physically locked to the concrete form.

Nevertheless, it is important to change as it is a big barrier to many electric car drivers.
Looking at the payment problem, it is easier to compare with the payment solutions currently available at petrol stations. Payment is payment and does not change as much as the other infrastructure does.
Today, payment is roughly the same throughout Europe as it is possible to pay with VISA or Mastercard at the existing gas stations.
From an ANT perspective, one can say that it is important that there is an actor who brings together all the different players in a common actor world. This has been the case in the Netherlands where the state has determined that there should be roaming between the different actors in the charging market. In practice, it means that as a customer you can charge everywhere, at all the companies that provide charging simply by having a chip or beta card for one of the places.

In the Netherlands you can charge with any card from one of the providers on all charge points. It could be quite expensive to charge at one of the competitors, but it is possible to charge. It has been made by law to make it easier for the consumer. Compared with the infrastructure challenge it is to have different payment method, it is a smart feature.
Martin Messer Thomsen, FDEL

The customers do not necessarily always get the best price, but the state has generated a common actor world, meaning that in Holland, it is always possible to pay, you just need one card or chip from one of the companies. Perhaps it could be a solution for the entire EU.

Within the Danish borders there is also an interesting solution on the way, which implies taking a whole new type of player into the network of payment.

Another challenge with electric cars in Denmark is that you need to have a chip for charging. It must first be sent to customers. Now, with E.ON, you can charge on all the stations with the easy park app.
Martin Messer Thomsen, FDEL

The EasyPark app is a successful Danish app, where you can easily pay for your parking. The smart thing is that you can extend your parking without going back to the car, instead just add more time in the app from your phone.
E.ON and Easy Park have now made a collaboration where you can pay for charging through the app.
That is what in ANT terms can be called a translation. A new player has been enrolled in the network, which, however, has nothing directly to do with charging, but nevertheless end up playing a central role in the network.

IONITY – common payment
The network mentioned above, IONITY, is a major collaboration on a charging network throughout Europe. They will also come to cooperate for payment.
(...) but something is on its way, and in fact, E.ON and Clever have collaborated on high speed charging stations around Europe. They come

under a different name, which are not two companies but a joint company. It will be nice charging stations, with roof and architect drawn and maybe with a small shop and car laundry.
There you can pay with E.ON or Clever or a joint chip.
Torben Arent, FDM

The benefit of payment is that it is somewhat easier to switch from one standard to another.

And it will probably come relatively quickly. As soon as you get south of the German border, there are other systems. But I think that it will adapt quickly (common payment standard red.).
Torben Arent, FDM

Other actors will from a technical point of view easily be able to enroll any kind of payment in their actor world.
But as it looks like right now, there are many who would rather make their own smaller and
closed network.
There are two major reasons for that it is expensive to switch over to VISA or Mastercard, but also be course many of the companies believe that their customers is more loyal if they have a chip that can only be used to charge at them.

Many electricity providers want to do customer care more of them do not themselves drive an electric car so they think you can have a close and loyal customer relationship. As an association, we say to both Clever and Eon that over half of the customers have a card to both places. Eventually, one is a charge card and the other one is a subscription card.
Martin Messer Thomsen, FDEL

Most electric car users are nevertheless active in both networks, and often use both companies. One could do as they do in Holland and demand standardization between the companies. One can also say that payment with a companyspecific card is actantwith a very small network. But if the companies used VISA and/or Marstercard, they would get a actorin their network which has one of the largest networks within payment. But that is a question of resources. By numbers there are already – and definitely much more in the future more charging stations than there are gas stations now.

It does not cost much to add a card reader to the fastchargers, but on public chargers, of which there are over 1500 in Copenhagen, it is not that straightforward. They have used the technically easy solution with charging chip or charging cards. And of course they want to keep their customers. As in the Netherlands, it has been said that there must be roaming between all the operators.
Martin Messer Thomson FDEL

In Denmark, as Clever costumer, it works fine, but if I go abroad it's a whole study how to pay for my charging. In Germany they have a hell of a lot of different companies on the market. In Lübeck, for instance the local power station set up a charger. It is free to charge, but the chip should be sent to you in advance.
Martin Messer Thomson FDEL

Some actors do not want to send the chip in advance but ask us to ask 'the guy Heinrich in the gate' to open so that we can charge. There may be far to southern Germany if you have to find one to talk with about the charging each and every time. The European infrastructure is also important.
Martin Messer Thomson FDEL
You can stand there with your mobile phone, credit card or cash, but have to give up charging.

Martin Messer Thomson FDEL

These small stories show the importance of gathering all the actors in one common actor world, who held the ambition of making payment easy and aim for a common European standard where there is roaming between actors like in the case from Holland.
Quite a lot of the actors are closed around themselves, and only pay interest to their own clients, and do not have a vision of creating an easier world for electric car owners.

We had borrowed a Tesla for a weekend and experienced in a parking lot in Hamburg that we could not charge because we were not 'regular customers'. The service could not just be bought. One should have bought a card with subscription several weeks in advance from home. Foreigners who come to Denmark also have difficulties loading at the Danish charging stations. It has become easier with apps, but still it is not easy.
Martin Messer Thomson FDEL

As the previous example with payment through easy park shows, the cellphone and app market contains a potential for gathering the European actors in a common actor world, since it will cost too many resources to equip all the charging points with VISA/Mastercard readers.

The Germans were slow starters, so they have found out that when power is taken from the CSS combo quick charger, it can recognize the frame number of the car and thereby know which agreement the car owner has about the payment. Imagine a solution that does not involve payment but confirms a trade via data transfer and subscribing. CHAdeMO, on the contrary, does not register which car, but only that “now there is a car”. They have the technical capabilities, but CHAdeMO and the Japanese car manufacturers refuse for unknown reasons to identify which car is charging, but the Germans want to identify it.

If it is possible to register the car number while charging, it opens up for new possibilities for easy payment, where the CSS combo as a plug standard can play a central role.
With this technical opportunity CSS combo can be a translatorspokesman for a payment standard only based on a subscription connected to the car and a smarter solution where you don’t have to bring along any chip, card, cash VISAcard or other type of payment.

On the other side, there may also arise many questions about personal data as one's driving pattern and route becomes clear and advertisements can be sent on that basis and the employer can follow the employee clearly.
Martin Messer Thomson FDEL

The quote shows how new challenges arise when new technology emerges. The development of electric cars also means that there are several dilemmas about personal data, privacy and potential surveillance.
This means, in practice, that you can follow a person's journey through Europe if the person uses CSS combo.
Conversely, if a person who has CHAdeMO, this person cannot be monitored to the same extent since the specific car is not registered.
Conversely, it is also smart just in relation to the thematic approach.
Frame number recognition could potentially open up for subscription schemes, where you could completely avoid a chip or card that will not work for all the different providers anyway.
Therefore, one can say that there is another smart advantage of the CSS combo plug, as it may potentially make the payment part easier. The flipside of the coin is that there can be challenges with personal data, surveillance and private life

Discussion

In this chapter I will discuss the tree standards and finally reflect upon payment.

Tesla's own actor world

Latour has introduced the framework actor world, that is also described in the theory chapter. Actor world can also be described as “an actor with a vision who try to enroll some other actors in their actor world”.
In that light Tesla is an interesting case, because they do not need to enroll other actors in their actorworld, because they have the hype and capital to all the investments by themselves.
It has much to do with Tesla's own vision of supplying all components to make it possible to handle supplies exclusively with Tesla products. It is the ambition that you can be disconnected from the main grid and get electricity from your own Tesla solar cells in the form of a roof tile.
With them it is possible to recharge your own Powerwall (battery for the house) and thus balance supply and demand so there is power even when the sun is not shining.
The car can also be included in the same circuit and be charged and may return power to the house if necessary.
In terms of infrastructure, Tesla has built a good network of superchargers, but it is reserved for Tesla's own customers, so other cars cannot charge there. This is an example of how Tesla is creating its own closed world.

Especially in less developed countries there could be a great advantage in being selfsufficient and closed circuits. In other words, Tesla is not dependent on getting the utilities to join their actor world.
Nor are they currently dependent on or interested in getting other electric cars to charge power at their super charger stations that are located in a fairly close network around Europe and the United States.
At first, Tesla was clearly a front runner and there was a lot of hype about the brand and vision.

CSS combo - A powerful player?

The CSS combo plug standard does not currently have the same technical benefit, namely that the car also can deliver power back to the network as CHAdeMO standard can.

On the other hand, the plug is built to handle significantly more power. CSS can handle up to 350 kWh,.

If we focus on Denmark and EU, the CSS combo is clearly seems that the standard has enrolled some stronger players around them in their network. In CSS combo's actor world, we find the largest German car brands such as the BMW Group, Daimler AG, the Ford Motor Company and the Volkswagen Group with Audi and Porsche. Thus, it is virtually the whole European car industry that is involved in the CSS combo network.

In addition, we find another very important player for the European Union who has decided that the CSS combo should be a standard in Europe.

In addition, the CSS combo standard also has the large common European network IONITY as a central actor in their actor world. You can say that IONITY becomes a spokesperson for the CSS combo plug by promoting the standard and freezing out the CHAdeMO standard. Each time the network issues a press release or otherwise promotes itself, they act as a sort of spokesperson for the CSS combo standard, which is the key player in the network.

Looking at the matter from a format war angle it is a big loss for CHAdeMO not to be in the prestigious European network.

The CSS plug has technically the ability to be upgraded and thus make it possible to send power back into the network without requiring a change of plug shape. On the other hand, CHAdeMO who was first mover and therefore an older standard, has to upgrade the shape of the plug if they should be able to handle more power.

CHAdeMO – a good technical translator?

Looking at the Japanese standard CHAdeMO, there is no doubt that this standard has a major actor world, because it is through translation it has managed to capture the grid and supply network and ad capabilities in their actorworld by constituting a very important blackbox feature to add stability to power network as described in the mini case at Roskilde Festival in the analysis section.

The company that one of my informants is working for the US company NUWEE is working exclusively with the potential of using electric cars set for charging with the blackbox function of stabilizing the power grid as described in the analysis part. Det foregår ved at bilerne selv sender strøm tilbage i nettet når belastningen er så høj at behovet opstår. Bilejernene belønnes i kroner øre for at levere strøm tilbage i elnetværket. This means that the CHAdeMO stand has a vision or potential pulled the all the players within the grid into their own network. In addition, it can be said that a technical solution to reward electric vehicle users also entails that the actual vehicle users are increasingly drawn into the network. In a Danish perspective, Nissan Leaf is also the bestselling electric car and is therefore far more widely used – so far.

Payment

One thing I was not so prepared for when I began to deal with the topic and made my interview guides was that it was quite a big problem for electric car owners to pay for their charging as soon as they drive across the country's borders.

At petrol stations across Europe, almost all of them were previously equipped with either a possibility to pay with either VISA or Mastercard or a shop where it is possible to pay with the local currency.

With the development of the electric car and associated charging, all companies within the business have created their own chip or card, probably with a desire to create greater customer loyalty. But it makes it difficult to pay for power, when you do not have one of the companies'

cards. Even in Denmark, the vast majority of electric car owners have a chip or card from both E.ON and Clever. And when traveling abroad it will be even worse. In short, on the verge of being unable to pay for the charging of electricity, if you are not a customer of the relevant company. One can discuss whether there is a paradox in the fact that the various companies in the charging industry try to create greater customer loyalty for themselves but at the same time may create less likelihood of choosing the electric car here in the transition phase, where the gasoline car is still attractive to many.

It is simply too cumbersome with all the subscriptions you should have, and as several of my informants told me, it was almost impossible to be allowed to pay for the electricity when you get outside your own country. In spite of the previously described format war between the standards where it in the best of all worlds it desirable to have a common standard, there may be a greater need to create a higher degree of uniformity in terms of paying for power.

It would be something that you could easily solve technically by agreement, like the example from Holland. As described in the analysis, they have made a law requiring roaming across actors so they avoid the problem but still have competition, so you can choose different companies, subscribers and discounts.

It seems very costly to equip all charging stations with a paycard reader. This would be a viable, but very resourcedemanding solution.

There is a need for an actor who is able to collect the various companies offering charging around Europe in a common charging actor world.

Conclusion

Through this master thesis, I have looked at which image you get of the infrastructure for charging in Denmark. I have found it necessary to look at Europe as well since drivers are moving around and there is obviously a need for a common infrastructure.
I have asked the question: How will the infrastructure for electric cars look like in the future? Which kinds of alliances are created and what kind of network does each plug standard have?

And as a Sub question: Is there a need for increased standardization of payment for charging?

At the present moment, there is no consensus on a common standard which would be the best for electric car customers and for the sale of electric cars.
There are, however, 3 different standards: Tesla’s own, which in the master thesis is not discussed that much as it is mostly closed around it-self. Tesla tries to bulid up an actor world, where each household is self-sufficient with Tesla's solar panels for both houses and cars. Possibly, with a battery in the house to balance demand and supply.
Others cannot use Tesla's charging network, but Tesla cars can use the CSS combo, and even CHAdeMO through a special adapter.
Between the two other dominant standards, there is currently a format war between CHAdeMO and CSS combo. Right now, both plugs are present at many charging stations, but it will not be possible to use CHAdeMO on the new Common European prestige network IONITY.
The two types of plugs each have some advantages and disadvantages and their networks have a different character.
The Japanese CHAdeMO standard currently has the technical advantage that it can return power back to the network.

It provides a large network within the electricity supply industry, as many electric cars can become a key player in stabilizing the electricity grid, as described in the analysis.

The CSS combo plug has the concrete advantage that the plug can handle significantly higher inputs (350 KW / h versus 50 KW / h in CHAdeMO). It means faster charging.
The CSS combo has a different but also large and powerful network. In addition to most European car manufacturers, the CCS combo is also the central standard in the IONITY charging network.
It is difficult at this time to say something about which standard will win the battle of formatting and it is also highly likely that both standards will exist side by side. Possibly with regional differences, i.e. CHAdeMO becomes dominant in Asia and CSS combo in Europe and America.

Payment

When it comes to payment for electricity along the roads, there is the same problem with the lack of standardization. Thus, there are several standards in the market that cannot work with each other. The problem is particularly serious when moving outside the country's borders. In Holland, a law has been made demanding roaming between actors, thus creating a common actor world within charging. Technically speaking, it is easier to create common standards within chips / cards. Perhaps a similar legislation should be formulated within the EU?

Perspectivation

It has been exciting to work with a project that extends so much into the future as the case has been.
But it also raises a lot of questions about which alternatives there might be.
I have in the master thesis I have mostly dealt with private passenger cars. How is the development within heavy transport?
What about ships and ferries – There is already electric ferrys that are operating, the next generation of seabusses in Copenhagen are planned to fully electric.

There are also issues of sustainability of different nature. No doubt that electric cars emit less CO2 than gasoline cars. But, of course, one have also looked at how the electricity for the cars is produced and attempted to analyze the CO2 accounts in that context.
It could also be exciting to research in battery technology and see which competitors for the lithium battery there are about to enter the market in the future. Lithium is a limited resource like all other raw materials.
There, for instance, are attempts to make batteries of more organic substances.
In addition, it could be interesting to compare Denmark with Norway and look more at the political processes and what could be done on the society level to improve a positive development for electric cars.

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