NORTH SEA REGION ELECTRIC MOBILITY NETWORK
e-mobility NSR

Danish Experiences in Setting up Charging Infrastructure for Electric Vehicles with a Special Focus on Battery Swap Stations

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List of abbreviations

BSS – battery swap station

CP – charging point

EC – European Commission

EU – European Union

EV – electric vehicles, 100% electric vehicles

FCP – fast charging point, generic name covering all types of fast charging points

ICE – Internal Combustion Engine

ICT- Information Communication Technology

QCP – quick charging point, the name of the fast charging infrastructure operated by CLEVER in Denmark

Please note that:

- By charging infrastructure is meant both BSSs, CPs and QCPs.
- By home charging stations all the private charging spots are meant: both at home and at the work place.

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Preface

This report was originally planned to treat mainly Battery Swap Stations in Denmark, but during the report elaboration process it occurred to be that performance of Battery Swap Stations is strongly connected with and supplemented by the other types of charging infrastructure (especially fast charging infrastructure), hence all the charging solutions operating in Denmark were also described. Moreover, electric vehicles development and spread is also an important factor for BSSs performance: if there are few on roads then for sure it will affect the BSSs' profitability. Therefore EVs with switchable batteries available in Denmark were also described in this report. Also an issue of deployment of smart grid deployment and the use of renewable resources was included in this report as it enables Battery Swap Stations' profitability and enables EVs to be really environment friendly.

This report has been produced as part of the E-Mobility NSR project by: Hanna Baster, Kent Bentzen, Emina Kapitanovic, Michael Laugesen and Morten Møller.

Special thanks to all who have contributed and accepted to be interviewed; an extensive assistance was provided by Better Place Denmark, but also by Dong Energy and Danish municipalities: Randers Municipality and Frederikshavn Municipality, who devoted their time to take a part in 1-2 hours long interviews and were willing to answer the follow-up questions.

Introduction

EU policies directed on electric vehicles

According to the European Recovery Plan, the European Union has selected various research and development support mechanisms in order to potentially achieve innovation in road transport and more specifically renewable CO_2 free energy sources and transportation means. Within the acknowledged fact that convenient CO_2 producing fuels are becoming more expensive and rare, it has been decided to focus on the potential alternative fuels that could provide green energy. There are various project initiatives as stated at the European Commission website concerning clean transports, "Clean transport, Urban Transport" (European Commission, 2011).

One of the projects is North Sea Region Electric Mobility Network (E-Mobility NSR), one of the objectives of the project is to demonstrate user friendly infrastructure with existing scalable technical solutions using existing sustainable business platforms for charging techniques. Currently many cities and regions in Europe NSR are developing coordinated action plans and strategies to develop electro mobility infrastructure. The core focus of these incentives is local and regional traffic. One of the biggest issues that E-Mobility NSR project is dealing with is organization and synchronizations of the different incentives with one another. E-Mobility NSR will help to create favourable conditions to promote the common development of e-mobility in the North Sea Region. Transnational support structures in the shape of a network and virtual routes are envisaged as part of the project, striving towards improving accessibility and the wider use of e-mobility in the North Sea Region countries, (E-mobility NSR, 2012).

This project has its roots in Europe 2020 strategy, where the European Commission gives the proposition of the Flagship Initiative 'Resource efficient Europe'. This underlies that the European Commission is going to focus on presenting and developing different kinds of projects in order to decarbonise and modernize the sector of transportation. As the reasoning behind this initiative is the fact that as the IEA has brought to the attention of the EU governments, the least the success in decarbonising the world, the greater the oil price will increase. In 2010, the oil import bill for the EU was around € 210 billion. If this issue is not adressed imediately it could lead to decreace in people's ability to travel, the decreased economic independence, distortion of trade balance and very high inflation due to the fact that almost all product and service prices are interrelated with oil prices in one way or another (European Commission, 2012).

At the same time EU has developed the so called White Paper (*Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*) that deals not only with economical issues, but also the need to reduce greenhouse gas emmissions. One of the common aspects that this papers deals with is to halve the use of conventially fulled cars in urban areas by 2030 and complete phasing out by 2050. European Commission has developed a road map according to which the GHG emissions decrease by 20% compared to 2008 numbers is required by 2030. This substantial decrease would bring EUs' GHG emissions 8% above the level of 1990. It has been concluded within the White Paper, that a succesful infrastructure development and potential reach of the settled goal would require over 1,3 trillion EUR investment in a period of 2010 and 2030. From that the successful completetion of the TEN-T network would require € 550 billion including removing the main bottlenecks of the transportation industry. Unfortunately, this does not include the potential investment in vehicles equipment and charging infrastructure that may require an additional trillion to achieve the emission reduction goals for the transport system.

E-mobility chances to become a mass market product

This report focuses on one of the EVS' charging infrastructure elements: the Battery Swap Station. This solution was recently developed and is currently under firsts market launches in Europe. The biggest European launch takes place in Denmark, where the whole country is planned to be covered with the Battery Swap Stations network enabling travel from the very north of the country to Copenhagen (516 km).

According to Better Place, an electric car is a vehicle of the future. In the past years, most of the major international car manufacturers announced various electric car models. It is uncommon to open a newspaper's car section or a car magazine without stumbling on electric car news, reports and reviews. Major automakers like Volkswagen, BMW and Audi will launch their first pure electric models. Already in 2011, it was noted that new mass-produced electric cars appeared on the roads' of Denmark such as Mitsubishi iMiev and Peugeot iOn. Furthermore, one of the core focuses of this project and Better Place is Renault's first full scale production of electric vehicles with removable battery, namely the Renault Fluence ZE, which was launched in 2011.

The Renault Fluence Z.E. is so far the only model that fits Better Place's battery switch concept. The Renault Fluence is introduced with a competitive price of 206.000 DKK (around 27.500 Euro). The reason for that is not only the desire of Better Place and Renault to push these products out of the market, but also various Danish government and EU initiatives for example a large role in decreasing electric car price in Denmark is played by different incentives, where owners of electric vehicles do not have to pay any registration taxes on their vehicles.

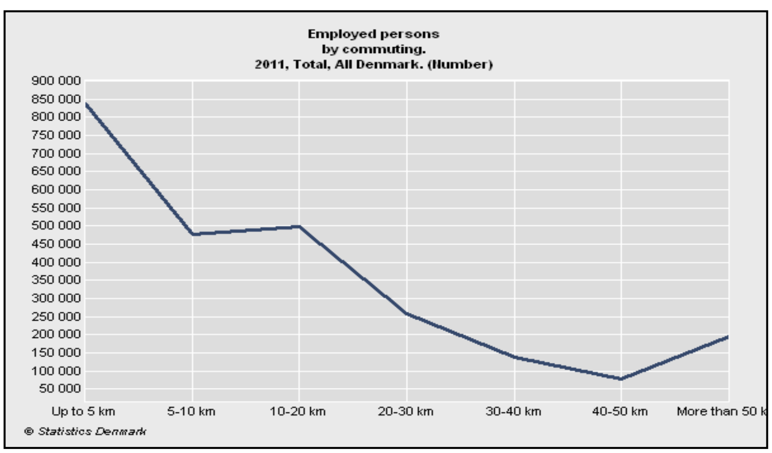


Figure 1 Commuting distance in Denmark, (Danish Statistics, 2012)

Additionally, taking into account Denmark, e-mobility has quite good chances to become a mass market product, because the average travelling distances fit quite well into the EVs range. If commuting behaviour is concerned, the average travelled daily distance for commuting reasons accounts for 39.4 km. The percentage of commuting trips in Denmark exceeding the average (100 km) and minimum (80 km) range of Renault Fluence is 7.8% (194 000 Danes) and 11% (273 646 Danes), respectively (Danish Statistics, 2012).

The reasoning behind choosing electricity powered vehicles against ICE vehicles

Electric cars have the potential to set new standards in the automotive market. Nissan's first electric car the Nissan Leaf has already being elected the 2011 European Car of the European motor journalists (Car of the year 2011, 2012). The Nissan Leaf was in direct competition with ICE models, which was launched the same year.

Within economies of scale an electric car is cheaper to produce than a fuel-driven car, because it primarily has fewer moving parts. Therefore, in general electric cars each year are becoming more competitive. From the user point of view, the fewer moving parts also mean less wear and less visits to the workshop when it comes to the maintenance of electric cars.

Besides these advantages electric cars have further benefits towards convenient vehicles. This applies to the acceleration capacity, because of the constant torque electric motor. Furthermore, theoretically, an electric car can utilize energy 3-4 times more efficiently than a conventional car.

With electric cars on Danish roads, traffic noise impacts can also be reduced substantially. The noise from the tires at high speeds is dominating, but at lower speeds below about 50 km / h, engine noise is the biggest problem especially in urban areas. It has been shown that over 785,000 homes are impacted by road noise, which is higher than the limit that is required by the governmental standards (Miljøstyrelsen, 2012). Furthermore, Denmark is experiencing between 200 and 500 premature deaths caused by road traffic noise and between 800 and 2,200 hospitalizations due to road traffic noise each year. An electric car has a great potential in relation to reduction of road traffic noise. Despite of the facts presented, concern about the threat of traffic accidents caused by soundless electric vehicles should be also taken into account. Researchers around the World work to identify whether this is a real problem. The challenge is to keep noise levels below the noise emitted from conventional engines, so that electric car noise reduction potential is preserved. Therefore, it is essential to work on creating a sound that is as silent as possible, but still stand out from the noise of the traffic.

Moreover, with regards to security, modern electric cars are fully comparable with the fuel-based ones. It is because they are produced by leading international original equipment manufacturers, whom all have extensive experience in automotive safety - and make the same demands on their new electric cars, as their fuel-powered models. That means for example that electric cars go through the same crash tests and safety procedures as those known for fuel-powered cars.

Another important factor to mention is air pollution decrease. Air pollution caused by transportation is one of the factors affecting public health most negatively in Denmark. The problem of air pollution in relation to public health is greatest in larger cities where people are on or close to busy roads. Pollution from fuel-powered vehicle exhaust emissions is the most harmful air pollution, because the discharge is at street level and because cars emit large amounts of ultrafine particles. Ultra-fine particles are particularly harmful, because they can reach all the way out of the outer branches of the lungs, where they are removed slower than the coarser particle types by, for example, wear of the tires, road surface, and brake blocks. There is still lack of knowledge about air pollution impacts, but recent scientific studies estimate that air pollution annually causes: approximately 3.400 premature deaths, 2.200 hospitalizations due to cardiovascular diseases, 1.500 hospitalizations due to respiratory diseases, 3.300 cases of chronic bronchitis, 11.600 cases of acute bronchitis in children under 15 years and 160.000 asthma attacks (National Institute for Public Health, 2007).

Not only have electric cars no exhaust pipe and they do not pollute at street level but also decrease emissions of tire and especially of brake dust. The amount of brake dust decreases dramatically with electric cars, as modern electric cars use so-called "regenerative engine braking," which virtually no wear on the car brake pads during braking, and which also recharges the car battery.

External factors justifying rationality of electro mobility implementation

There are several factors suggesting that there is a need for the Danish transport sector to adapt to renewable energy sources. Firstly, rising pollution emission and significant climate change has resulted in a need to reduce and eventually eliminate polluting emissions from oil-based transport altogether. Moreover, oil production is approaching its peak and oil companies are increasingly seeking for “hard to reach” sources of oil, which is both costly and difficult to extract. Furthermore, there is an increasing demand for more energy, especially oil, which is expected to rise significantly in the future. This phenomenon can be especially observed in countries with high growth of economy and population for example countries like China and India, where living standards are rising and millions of people buying their first car, first refrigerator as well as increase their travel activity. All this requires more energy coupled with the emission of more CO_2.

Renewable energy creates sustainable transport and vice versa. The economy that is possibly using the renewable energy creates a great opportunity in the transport sector. A significant proportion of renewable energy in Denmark is generated by wind energy. Unfortunately, wind energy is difficult to exploit optimally: when there is no wind needs of Danish households are hard to be met, while when it blows, there is contrariwise not always sufficient demand .Continuously, Denmark sells it below the cost of production, gives it away or even completely stops the wind turbines in periods of times. Better Place has developed a sophisticated software system that takes into account electric car drivers’ driving needs, possible local overloading of the power grid and a number of other factors. The better utilization makes it possible to increase the production of wind energy in Denmark. Further, the increased power consumption due to amplified use of electric cars would theoretically increase the price of EU CO_2 allowances and would make investments in energy efficiency and renewable energy more profitable.

Over the past 35 years the global demand for oil has raised in an average of 1% per year, and the global oil trade crossed the full $ 3 trillion in 2008 and global demand for oil and gas continues to grow. In fact, many estimate that the world in 2050 will demand twice as much energy as today. Dwindling oil reserves and a consequent rise in global oil prices have almost unimaginable consequences, not just for climate, but also for our transportation systems. Fortunately, the future holds equally great potential for a corresponding global transportation market based on renewable energy. A shift to a transport system based on renewable energy will inevitably lead to a substantial reduction in demand for oil, and can potentially create one of the 21 century's greatest economic opportunities. The expansion of renewable energy is just one way of creating value. Investment in electric vehicle components, infrastructure and systems, batteries, charging stations, battery switch stations and network technologies will result in new jobs in numerous industries. The shift to electric cars will also allow for savings in the transport sector.

Why Denmark was chosen as a Battery Swap Stations demonstration site

A modern society like Denmark emits a great amount of CO_2 into the atmosphere on a daily basis. The imminent threat to the climate is the reason why Denmark is by 2020 obliged by EU's goal of reducing greenhouse gases by 20% compared to 1990 levels by 2020. In Denmark, transport accounts for more than 20% of total CO_2 emissions. A figure like that is difficult to reduce despite of the fact that tighter environmental standards for cars have been gradually introduced. Just since 1990 there have been almost half a million more cars on Danish roads. So even though cars are more energy efficient and run longer on a litre, there has not been shown a decrease in total CO_2 emissions. Electric cars can play a crucial role in reducing CO_2 emissions, as a petrol car with an average driving pattern emits about 3.3 tonnes of CO2 per year, while an electric car is to bring the figure down to about one ton of CO_2, mainly due to electricity production.

An electric car will also be even more eco-friendly over time. Denmark's stated goal of increasing the share of renewable energy such as wind energy in the grid, means that the electric car's indirect CO_2 emissions from electricity generation at the power plant is reduced, as the power generation becomes more climate friendly. This is even more probable, as charging infrastructure operated by Better Place (home charging stations, public charging points and the battery swap stations) are already connected to smart grid. The electric car is not just a here-and-now alternative, but an investment in a sustainable future. Danish Energy producers expect to halve CO_2 content in the Danish electricity production already in 2025. This goal is to be greatly supported by charging infrastructure for electric vehicles integration with the smart grid.

Methodology

Aim

Battery Swap Station is a new solution, which has not previously been described in scientific reports or journals. This report aims at communicating this solution to a broader audience, especially focusing on public authorities of NSR countries.

Geographical scope

Denmark was chosen as a geographical area for this report, as this is the first country in Europe where a BSSs' network has been established.

Goals

The report's outcomes are intended to assist a sound development of e-mobility policies in the NSR countries: firstly, it will provide information which will help to influence public authorities to support e-mobility spread with legislative and financial tools, secondly, it will provide them with descriptions and comparisons of the existing charging infrastructure solutions (BSS, CP, FCP), thirdly it will inform them about the needs concerning these tools development, thus optimizing the procedures of setting up smart grid solutions in connection with Battery Swap Stations and Charging Points. Last but not least the goal of this project is also to inform them about the possible gaps, which may hamper this infrastructure launch.

Objectives and outcomes

There are established two main objectives of this report. First one is to describe a new charging solution – battery swapping and second to create a roadmap for a successful establishment of Battery Swap Stations' network in the North Sea Region countries accompanied with the recommendations concerning changes in the law required to smoothen the process of charging infrastructure implementation.

The goals were attained by presenting the process for swapping batteries as well as the setting up of the stations including connections with smart grid solutions. This activity has a special focus on the physical setting up of the BSS's. Second goal was accomplished by elaborating on the process of BSS establishment, concentrating especially on the legal side of this activity: beginning with location criteria, going through permissions needed and finishing with financial and legal support provided by public authorities. The first main outcome of the report is a description of the BSS establishment process in Denmark, with a special focus on legal aspect. The second main outcome of this report is a roadmap for BSS implementation consisting of a description of BSS establishment process in Denmark accompanied with the recommendations concerning changes in the Danish law required to smoothen the process of charging infrastructure implementation.

Detailed outcomes' description

Through the demonstration of the procedure connected with charging infrastructure set up in Denmark the report aims to firstly attain information on **location criteria considered as most feasible by BSSs and CPs establishers** and how they sometimes have to be changed due to public authorities' preferences. Secondly, the report wants to collect information on **legislative processes related with BSSs and CPs set up**, permissions necessary and the timing needed for their acquirement is described. Thirdly, the report endeavours to examine **process of the physical BSS and CP establishment**. Last but not least, the report gives an insight into smart grid solution with charging points present in Denmark and by this into **Danish experiences with using renewable resources for EVs charging**.

Process (Data collection protocol)

The report was written on the basis of a literature review, Danish planning and building regulations review and interviews with core stakeholders. Extensive assistance was provided by Better Place, but also by the other interviewees: Dong Energy and Danish municipalities: Randers Kommune and Frederikshavn Kommune.

Report's structure

Chapter 1: this chapter provides the reader with location criteria considered by Better Place while choosing a spot for a BSS establishment. This information was needed in order to comprehensively describe the process of BSSs setup in Denmark. The chapter was written mainly on the basis of an interview with Better Place. Additionally websites of Better Place and CLEVER were used. Better Place assisted extensively within writing the whole project, but especially concerning this chapter, as information provided was not accessible publicly. Core inputs were received at a meeting with Better Place in May 2012.

Chapter 2: background knowledge for this chapter was gathered on the basis of the Building Act in Denmark and the Danish Planning Act documents. Interviews with Danish municipalities provided the most important information for this chapter. Information gathered from Frederikshavn Kommune and Randers Kommune enabled the author to map the process of BSS physical establishment in Denmark – from finding the right spot to the BSS opening. Furthermore, knowledge gathered during conducted interviews helped to point out weak points within the Danish Law system concerning electric vehicles, charging infrastructure as well as e-mobility spread in general.

Chapter 3: technical operation and physical set up process – The main goal of this report is to provide a roadmap for charging infrastructure implementation and not to perform a research on the technical side of the issue. However, it was important to include technical issues in this report, since recommendations cannot be elaborated without a basic knowledge of the general technical features of charging infrastructure. It was especially important regarding Battery Swap Stations as it is a new, not broadly described solution. The chapter was written on the basis of an interview conducted with Better Place, but also on the basis of secondary data sources: websites, reports (especially from the EDISON consortium).

Chapter 4: As mentioned previously, the main goal of this report is to provide a roadmap for charging infrastructure implementation and not to perform a research on the technical side of the issue. However, it was important to elaborate on smart grid integration with BSSs as this limits feasible location of BSS, its profitability, and have an impact on permissions needed to be obtained to establish BSS. The chapter was produced mainly on the basis of interview with Dong Energy and Better Place. Nevertheless, literature review on smart grid and electricity supply system in Denmark provided an important background to build the proper questions for the interviewees.

Chapter 5: this chapter describes existing charging infrastructure for EVs network in Denmark and endeavors to compare its elements: Battery Swap Stations and Quick Charging Points. This comparison, together with recommendations from chapter 10 could hopefully help public authorities to decide which solution is most feasible for specific locations. Although, it must be noted that this chapter does not try to give a final recommendation on which solution is more feasible, but is meant to serve as an additional, advisory tool.

Chapter 6-10 aim at summarizing and reflecting upon findings described within chapters 1-5, so the information gathered during interviews and from secondary data sources.

Chapter 6: This chapter presents strengths, weaknesses, opportunities and challenges (threats) of the Battery Swap Station network in Denmark. It does not analyze the impact of BSS, but rather try to assess chances for a successful BSS spread.

Chapter 7: this chapter provides the reader with the main established outcome for this report – process of BSS establishment in Denmark with a special focus on the legal side of the process. Chapter summarizes information presented in chapter 3 of this project, which were gathered from the interviews with municipal authorities (Randers and Frederikshavn municipalities) and Better Place.

Chapter 8: focuses on the future potentials of Battery Swap Stations use for freight vehicles. Firstly it elaborates on the possibilities for BSSs's retrofits for freight vehicles. Secondly, the chapter provides reflection on the opportunities for BSS deployment at logistics centers for serving electric freight vehicles used for city distribution purposes. Findings presented in this chapter are based on the information gathered during the interview with Better Place as well as on the basis of work package 7 activity 3 report (co-developed by FDT).

Chapter 9: present recommendations regarding BSSs, charging infrastructure and e-mobility development in general. This chapter is an attempt to put the issue of BSS into a broader context and reflect not only on how to successfully implement battery swap stations, but also on, in which situations and in which locations, it is needed and in which situations and in which locations it can occur to be undesired.

Chapter 10: sums up findings and presents conclusions from the whole report

Chapter 1 Charging infrastructure location criteria in Denmark with a special focus on Battery Swap Stations

1.1 General location criteria for Battery Swap Stations

Battery Swap Stations are established to ensure that also long drives (more than 120 km) are possible with an electric vehicle. Hence, BSSs are placed outside the cities, along the highways and main roads. The main goal is to enable drivers to travel between the biggest Danish cities: along the whole “highway H”, consisting of E20, E47 and E45. The BSSs network consists of 17 stations and enables travels from Skagen to Copenhagen. The distance between BSS is fixed this way, that the biggest distance is 100 km and the shortest is 70 km. BSSs are not expected to be often used; as can be found on Better Place website, “*...only about 5% of the Danish daily trips exceed the battery range, which is 160 km. Therefore, it will be necessary only in exceptional cases to change the battery on the way. Normally, charging at a charging stand cover most of residents' daily driving needs* (Better Place, 2012J).

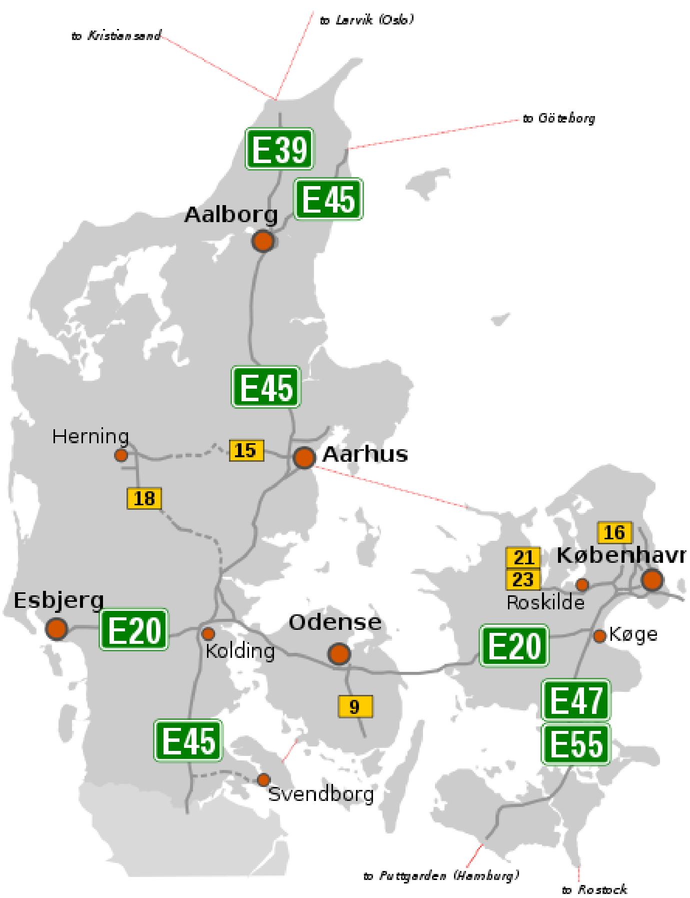


Figure 2“Highway H”, source: (Wikimedia, 2012)

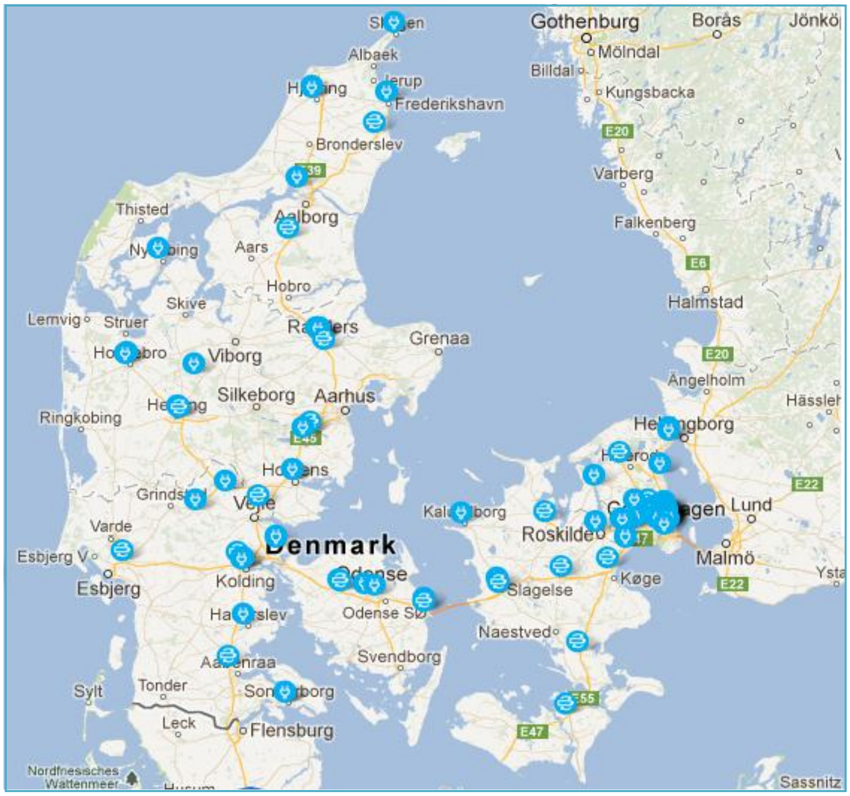


Figure 3 Better Place's Battery Swap Stations located outside the cities, along major corridors.

The BSS cost is 10-15 million DKK and it is the same as 750 charging spots. This is the reason why BSSs are mainly located only along highways, to meet the demand of people travelling long distance – when the battery switch is really necessary.

Additionally, there are plans to locate several BSSs within the cities' boundaries, when a bigger number of electric cars will appear on roads. It is because BSSs could be more feasible than FCP for EV drivers living in high rise buildings, who do not have a space to install their own home charging station. The reason to establish BSS within the cities could be also queuing to FCPs, as the time of charging is still long (20-30 minutes CLEVER FCP; Better Place has so far not established FCP, only CP).

Currently, there was made an effort to locate one BSS in Copenhagen, in Ørestaden. One reason is to advertise BSS concept and the second is that a majority of expected first EVs users are living/working there.

1.2 Specific location criteria for Battery Swap Stations

During the interview conducted with Better Place, detailed location criteria considered by this company were described, as well as general ones, described previously. They are: accessibility, location/zoning, visibility, security, property price, property size and shape, neighbourhood. Below, a table presenting location criteria according to this prioritized under:

Specific BSS location criteria importance in the Better Place consideration		
Accessibility	1 (50%)	1 (30%)
Location/Zoning	2	2 (20%)
Property size and shape	3	3 (10%)
Visibility from road	3	2 (20%)
Price	3	3 (10%)
Security	4	4 (5%)
Neighbourhood	4	4 (5%)

Figure 4 Better Place location criteria for BSS in Denmark, (Interview with Thomas Greisen, May 2012)

Accessibility is measured as the most important one; its share accounts for around 50% during the decision making process. The explanation is simple: poor access to the BSS will cause decreased use of it, despite of good visibility. The issue of accessibility was connected mainly with the location close to the road, the possibility to enter the BSS enter from both sides of the highway/main road, risk minimisation when turning left while leaving/approaching BSS's and location outside of traffic-jammed areas. Therefore, BSS have been ,where possible, located close to the highway/main road exits which were accessible from both directions. Otherwise, BSS have to be built it in a double number. At one location, in Kildebjerg, Better Place did not succeed to achieve it, hence there are 2 BSS', one on each side of the highway.

Zoning and location

Furthermore location criteria depend on the existing planning system. It is an advantage if a chosen spot is already covered by a local plan and if a new does one not have to be established due to changes in land use.

In Denmark the utility companies has – by law – an obligation to supply the requested amount of Amps that any customer demand. They are also in their right to charge a price for such demand, at present time a one time off fee of DKK 495,- per amp is charged. Therefore quick chargers can be installed anywhere and the utility company has to supply the requested amps from a grid 'connection supply box' no further than 30 meters away from the cadastral, where you plan to put up the charger. Civil works, cabling and connection from the connection supply box to the charger will be on the charging infrastructure operator's own expense. Following this reasoning BSSs should be located next to the electricity transmission/distribution network and specifically next to transformer stations. However, a transformer station is located at each BSS site, it does not need to be located close to the general transformer station, but only close to the transmission /distribution network. Secondly it would be necessary as, the energy looses while transporting it on distribution network (no more than 50 kV, low voltage network) is much higher than on transmission network (no less than 110 kV, high voltage network). Access to water and sewage system is also important, when locating the BSS.

Figure 5 Kolding: BSS located next to highway exits for both directions, (Google Maps)

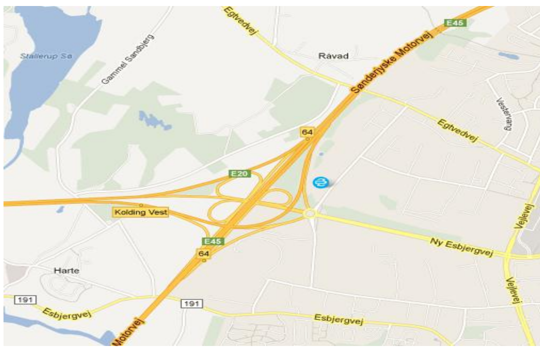
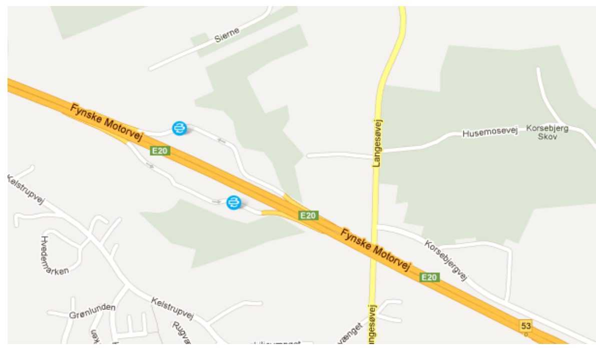


Figure 6 Kildebjerg: 2 BSSs next to each highway exit, (Google Maps)



Property's size and shape:

When it comes to the property's size and shape, it should be at least 800 m^2, as there should be space for BSS building (currently one swapping lane, in the future it is planned to extend with a second lane), 3 parking places and the transformer station. The main entrance to the BSS is on the left, when entering the battery swap lane, which also determines the required shape of lot. The important thing is to also ensure that none of the cables are under the building fundaments.

Figure 7 BSS's size and shape (Plugincars, 2012)

Visibility from the road:

Figure 8 BSS visibility (Better Place Danmark, 2012)

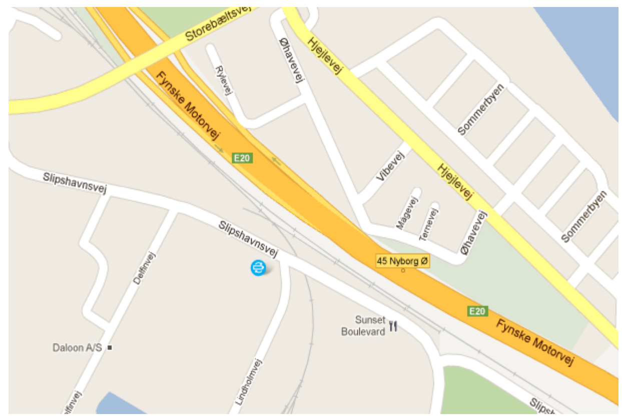


Figure 9 BSS location next to rest areas: Nyborg (Google Maps)

There are planned to be established road signs on the highway, namely: "Batteriskiftestation" (Battery Swap Station). Currently, there is only one in place, in Kolding. Better Place has already applied to EU for the design of a common sign for BSSs, but their request has not been yet processed.

As written above, visibility is also about proximity to places where people stop on their way: fast food chain, gasoline stations, rest areas, etc. The main reason to locate BSSs' next to rest areas is the visibility issue. Other issues like common technical services, maintaining services or bathrooms were not the determining factors.

Price

Renting the property is preferred. However, the renting time is desired to be at least 10 years long. In the majority of cases, the contract time in Denmark was established for 20 years. If the property had to be bought, then it was previously possessed by the municipality in the majority of cases. The price of the property includes: property value plus expenses connected with preparation of the property for the building placement.

Security

In order to ensure sufficient **security** at the BSSs, the following solutions were implemented: firstly, good area's lighting. Secondly, visibility also ensures BSS's security as it requires locations next to the rest areas: gasoline stations, fast food chains.

Neighbourhood

According to Better Place, there are no inconvenient **neighbourhoods** for BSS location; for instance in Nyborg it is located right next to a landfill. The preferred location is next to rest areas: restaurants and gasoline stations, where BSS can be visible from or where the sign directing to it can be put. Gasoline stations and fast food chains occupy the best accessibility locations and therefore BSS's are preferred to be located next to them.

1.3 Location criteria for charging points and fast charging points

Better Place has already established charging spots in the 30 biggest cities in Denmark. Charging Points are located only in the cities, as the charging time can take several hours. In order to charge the battery up to 80% with a fast charging facility (125 Amps) it takes 20-30 minutes and to charge it with a regular charging (16 Amps) it takes 6-8 hours, but then the battery is charge close to 100%. Therefore, for some it is more feasible to swap the battery at a BSS during long trips than to charge it. Charging points are located within the cities where there is people agglomeration: next to the top attractions, like Amusement Parks, ZOOs and shopping centres or next to hotels. The location criterion for this was that people stay in these places more than 2-3 hours. Therefore, for instance, it doesn't make sense to have a charging spot next to the bank. Clever is the second biggest company installing charging infrastructure for EVs in Denmark; besides of CP they have also implemented quick charging points (QCP). Location criteria of QCP are the same as for CP: within the cities' borders and next to restaurants and grocery shops. As can be found on the CLEVER website: "*Both the Quick Charge and normal charge can be an option, depending on the type of location. It is since both will be needed for charging in residential areas where electric cars typically stand all night or where short stops are made"* (CLEVER, 2012F). Even though there are QCPs located next to highways (in Nyborg and Køge), they are the only two while the rest of these facilities are located within the cities. This shows what the intended function of QCPs is: charging EVs used for short trips – within cities; for now Clever has mainly located their shops on Føtex (supermarket) properties. The reason for such location criteria is that QCPs are most feasible for short trips, while BSSs are for long trips. Neither Better Place nor Clever has located their CPs/QCPs within residential areas.

Figure 10 Nyborg, location next to the landfill, (Google Maps)

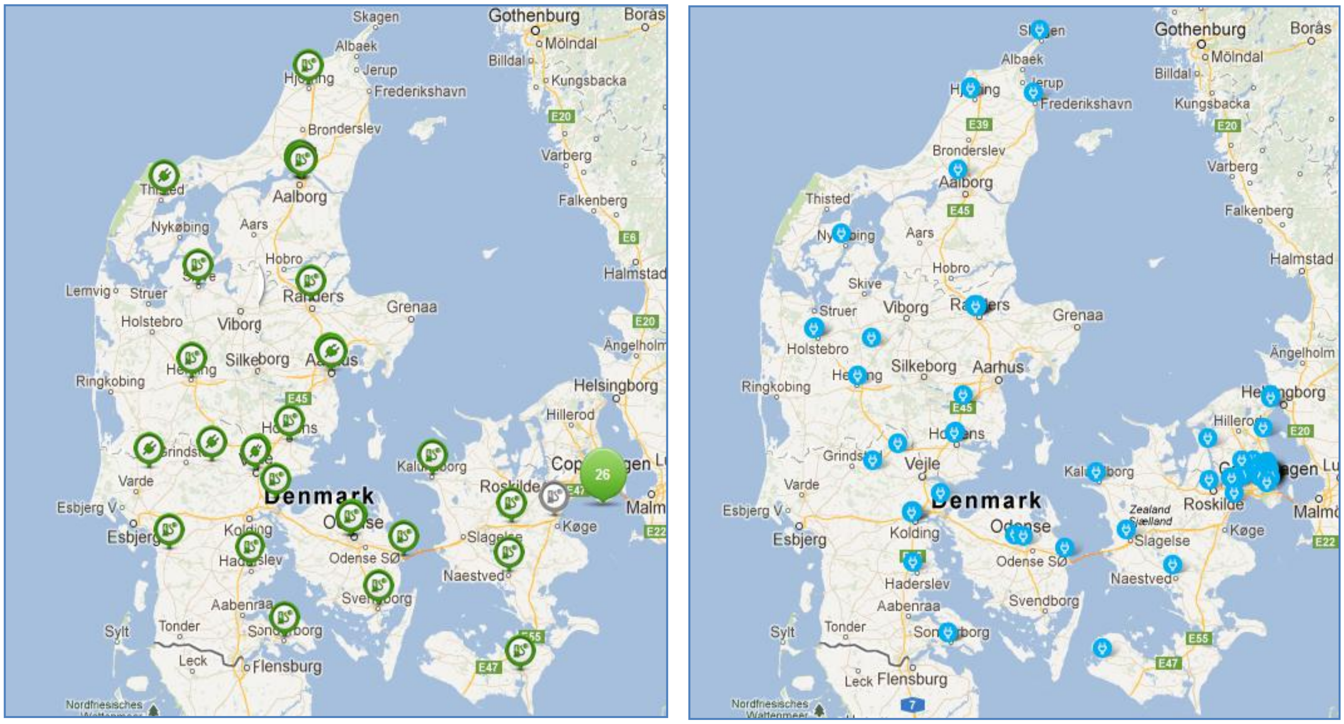


Figure 11 CLEVER's charging points and fast charging points and Better Place charging points location in Denmark, source: (Clever , 2012C), (Better Place, 2012B)

Besides of the location criteria for BSSs and CPs considered by Better Place and described in this chapter, the final spots location was influenced by the public authorities' decisions and supported as well. This issue will be further investigated in chapter 3 of this report.

1.4 Summary and conclusion

- Thanks to the location along the H highway, BSSs network makes it possible to drive from the very north of Denmark down to Copenhagen (516 km) and to the German border (403 km) without waiting for the battery to be charged at a charging station.
- The shortest distance between BSS is 70 km while the longest 100 km. The minimum range of an EV (specifically Renault Fluence Z.E.) with switchable battery is 80 km and therefore location of BSS is well suited for EVs range.
- The important measures considered by Better Place while acquiring property for BSS establishment are: accessibility, location/zoning, property size and shape, visibility from road, price, security, and neighbourhood.
- Location is only slightly determined by the existing electricity network location, since each BSS spot contains a transformer station, which lowers/increases the voltage as requested.
- BSSs are much more expensive than CPs and therefore they are and will be located mainly where CPs use is not feasible: outside of cities, along the highways, where charging time must be short.
- However, there are planned to be built several BSSs within cities limits in the future to enable multi storage buildings inhabitants to drive EVs. There were already taken steps to build a BSS in Copenhagen (Ørestad), mainly for marketing purposes.
- BSSs are not expected to be used daily by EV drivers. Taking into account that the max range of Renault Fluence is 160 km, only 5% of Danes would expectedly use it every day. However if average and minimum of a Renault Fluence Z.E. was considered (100 and 80 km), then the share would increase to 8% and 11% respectively, who would potentially use the BSS on a daily basis due to their commuting range.

Chapter 2 Legal issues: Grants and Permissions

2.1 Common permissions for all construction sites in Denmark

Denmark is in general an investor friendly country if international rankings are taken into account. When it for instance comes to the rank “Dealing with construction permits” for warehouse buildings published by World Bank in 2012 (World Bank, 2012), Denmark has a 10th position (out of 183 countries). Taken into account are time needed to build (33.3%), costs as % of income per capita (33.3%) and number of procedures (33.3%). There is 67 days needed to go through all 5 procedures written into the building permit obtaining process. Cost of obtaining all the permissions is 188,875 DKK what accounts for 59.1 % of income per capita in Denmark. Comparison of all North Sea Region countries involved into E-mobility NSR program is presented below.

North Sea Region country	Place in Rank	Time (days)	Number of procedures	Cost as a % of income per capita
Belgium	51	169	12	53.6
Denmark	**10**	**67**	**5**	**59.1**
Germany	15	97	9	49.7
Netherlands	99	176	15	107.8
Norway	60	250	11	33.1
Sweden	23	116	7	81.6
United Kingdom	22	99	9	63.8

Figure 12 Process of construction permits acquiring in North Sea Region countries. Comparison. Source: (World Bank, 2012)

Considering data shown above it can be reasoned, that the time of BSS set up in other North Sea Region countries will take longer time than in Denmark and will be more expensive. Worth mentioning is also that in the Danish planning system, permissions once applied for, do not expire.

The general permissions necessary to be obtained for every construction site in Denmark are: building permit, and either local plan or a rural zone permit. Denmark is divided into 3 types of areas: urban areas, rural areas and summer house areas. Local plans can concern any of these 3 areas while rural zoning permit applies only to rural areas. Rural zoning permit must be accompanied with a local plan when it comes to new constructions establishment. A building permit is necessary in all 3 areas and is awarded after all the permissions are obtained, including rural zone permit/compliance with local plan.

In order to obtain all the permissions needed, there must be delivered a documentation concerning technical building’s details. It is revised by the municipal authorities and when all the requirements are met, construction of the building can start. Technical documentation must contain:

A. *"Drawings showing level access*
B. *technical detailed BSS's building drawing including specific drawings concerning sewage system and fire protection system.*
C. *technical property plan,*
D. *drawings showing any sound insulation against neighboring properties,*
E. *drawings showing the tightness of the building where it is in contact with the soil,*
F. *stability calculations, documentation showing load-bearing structure of the building and these showing that structures were erected in line with the best building practice*
G. *documentation showing that structures and materials are free of any moisture content which would risk the development of mould in the building once occupied (engineer's report)*
H. *documentation showing that fire safety requirements have been met (in accordance with "Eksempelsamling for brandsikring af byggeri 2010" elaborating on fire safety measures in buildings,*
I. *energy performance framework calculations*
J. *heat loss calculations (for conversions)*
K. *documentation relating to sewers/drainage*
L. *documentation relating to ventilation* (The Danish Ministry of Economic and Business Affairs, 2010)"

In some municipalities it was possible for Better Place to start building before all permits were obtained. However, if it occurred that some requirements were not met and the building permit could not be issued, then Better Place had to stop the construction without borne costs' compensation, as was learned from municipalities (however, such a situation did not take place).

According to Better Place, the most important permissions to be obtained (needed in order to get building permit/rural zoning permit) while setting up a BSS are: transfer of the property from rural to urban zone (the making of a new local plan is necessary in this case), rural zoning permit and permissions from the fire department and concerning waste water management. The overall time needed to gather all the permissions took in the majority of cases few months, but in some locations it consumed up to 2 years. The longest time was needed in these municipalities, where a new local plan had to be prepared.

Building permit

The physical BSS establishment can start the moment the building permit is awarded, thus it is the final and most important permit required to set up a building. However, in order to obtain this permission all other requirements must be met: compliment with a local plan or obtainment of a rural zone permit, and obtainment of other permissions (described below in the subsection "other permissions"). CPs are generally exempted from the requirement of obtaining building permit, as they are treated as a small construction side ("mindre bygninger") according to the Danish Building Regulations document (The Danish Ministry of Economic and Business affairs, 2007).

Local plan

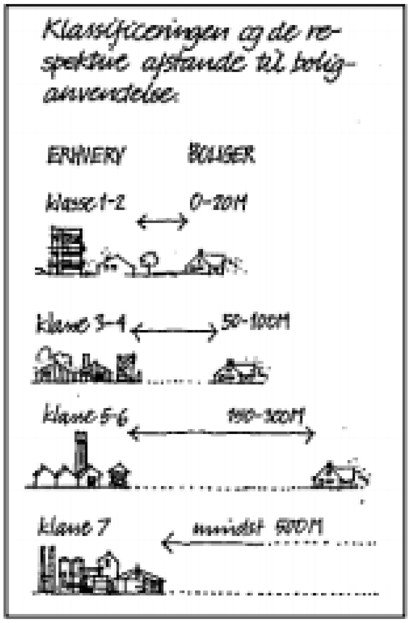


Figure 13 Distance from residential area required for respective environmental classes(Kommune Plan , 2005)

A local plan which covering the chosen spot, where the BSS is built is in general a required prerequisite to obtain a building permit. Though, it can be omitted if the municipality deems that a building does not have a significant impact on an area. If the chosen area is already covered by a local plan, then a new BSS must meet the terms of this document. If not, then a new local plan must be prepared for this specific location. Inhabitants play an important role in local plans' establishment. Their objections against new construction must be considered by the municipality. However, inhabitants do not possess a veto; public authorities can make decision against the public will, if necessary.

The procedure of writing down the area to the local plan took municipalities from 6 months up to 2 years (the time of waiting is the longest in Copenhagen, as the planning rules there are the most restrictive ones in whole Denmark). Even though time needed to change the property's use in the local plan was long, it did not slow down starting the physical BSS's set up process. It was a specific agreement between municipalities and Better Place: they could start building a BSS after all the technical documentation of the building was provided and preliminary decision of compliance with the local plan was given. Although, if it occurs that some requirements are not met and the building permit cannot be issued, then Better Place has to stop construction without borne costs' compensation. Moreover, the cost of writing local plans was covered by municipalities.

As BSSs are generally located outside the cities, along the highways, they are generally covered with a rural zone permit and not with a local plan. The situation is converse when it comes to charging points: their common location is within core urban areas: next to shopping malls and business centres. However, CP do not even require a building permit, they are only obligated to comply with local plans; according to Better Place, charging spots can be located more or less everywhere within city's borders of Copenhagen. Furthermore, in some municipalities, Better Place does not have to pay for a spot rented for CP establishment.

While being written into the local plan, BSS location is, among others, considered regarding environmental issues. There are seven environmental classes in the Danish planning system, where first class covers offices and small shops and the seventh refers to heavy industry areas such as power plants. In general, the higher class's number the harder to obtain a zoning permit for a specific place. If the business activity is within the first class, then it can be located within residential areas, while if classified to the seventh environmental class, the distance should be at least 500 meters. Another important issue, included in the local plan requirements is a maximum plot ratio established for each property, so to say the percentage of an area which can be built up.

Normally, it accounts for 40% for buildings other than houses and semi-detached houses. As BSSs are in most cases located in the rural areas (those not covered with a local plan), they are not covered with this limit. Therefore a maximum plot ratio can differ from property to property, depending on urban planners' decision.

Rural zone permit

Rural zone permits are especially important for BSSs as they are generally located at the cities' outskirts or in rural areas – always next to the highways/main roads. In Denmark it is hard to obtain a building permit at the countryside for commercial buildings with functionality different than agriculture, fishing or forestry. The other experienced problem connected with obtaining permissions for BSS built in the rural areas is that parcels[1] within these regions are of a large size and according to the Danish law, an additional permit is required to divide the parcel and sell only a piece of it (Randers municipality, 2012); obtaining this permit is especially hard in the rural areas. Therefore, when the parcel is too big, Better Place tend to rent it instead of buying.

Other permissions

Besides of the local plan/rural zone permit, several others need to be gathered concerning each building in Denmark: "examining the area plan, checking plans and drawings, checking the lot plan, securing fire department permission, issuing a temporary building permit, issuing the structural engineer certificate, checking the rain water drainage and checking building compliance with the Real Estate Registry's regulations and requirements for registration and specific projects" (The World Bank, 2012).

2.2 Specific permissions required to set up and run a Battery Swap Station

Citizens play an important role in the Danish planning system. Their objections against new constructions must be considered by the municipality. However, inhabitants do not possess a veto; public authorities can make decision against the public will, if necessary. In some municipalities all the permissions besides of local plans and rural zoning permit (fire, waste water, traffic, noise and safety) are issued by one department: traffic planning section, as BSSs and CPs are elements of transport infrastructure. In some other municipalities permissions concerning specific fields are issued by departments specialized in these fields. Nevertheless, municipalities try to gather representatives of all these sections around one table together with Better Place at the early stage, in order to quicken the process.

Municipal location criteria (environmental class)

BSS cannot be located right next to residential areas, as BSSs are generally treated as a similar construction to gasoline stations and therefore placed within either 3rd or 4th environmental class. The minimum distance is 50 m, when it comes to 3rd class and 100 m concerning 4th class. This can be conceived as an incentive from municipalities, as according to the Danish Environmental Class system, BSS should be located within 4th class, if car washing is present (as this is a requirement for gasoline stations with car wash). Each BSS possess washing

[1] Whole Denmark territory is divided into specific cadastrals, which cannot be easily further divided into parts and sold, especially in the rural areas.

equipment, as each time four locking points on the battery should be cleaned and (of precaution reasons), before the battery can be removed. However, not only can the BSS be treated as a gasoline station, but also as a small service industry, and therefore it is not important whether BSS possess washing facilities or not.

Safety, noise and traffic generated

Municipalities agreed that BSSs and CPs are not dangerous for the environment so that there is no need for the municipality to release a big number of permissions. As Thomas Greisen, Better Place's Senior Negotiator mentioned, during the interview, the only environmental issues to be considered are the fire danger and the dealing with waste water. Regarding the first, municipal fire departments were concerned about high lithium flammability. In regards to the latter, water should be stored in containers and then directed to the sewerage system. No permission concerning used batteries' utilization was required. However, as was learned during interviews, the reason for this is not lack of necessity for such a regulation, but rather the early stage of BSS implementation; in this moment location criteria and building permit where these of municipal interest.

On the subject of environmental issues, there was also required expertise connected with generated traffic as well as with the noise induced. However, after investigation, it was found that BSSs don't generate a significant noise level, as electric cars do not produce it so. Traffic produced would not be currently of the same scale as when it comes to this generated by a new gasoline station. Although, question of future level of traffic generated holds true.

2.3 Grants/ incentives provided by the Danish government and Danish municipalities

Municipalities in Denmark support directly charging infrastructure establishment, by e.g. speeding up this process. Municipalities also support indirectly BSSs and CPs by supporting electric vehicles spread in their own administration, encouraging citizens to use them, facilitating their driving, charging and parking. It is very hard to disconnect these issues: policies regarding electric vehicles and charging infrastructure. Hence, both of them: directly and indirectly supporting charging infrastructure spread will be described.

Direct support:

Danish municipalities possess planning competences and therefore stimulate charging infrastructure spread by allowing purchases of public properties for this purpose and by speeding up this process. Though, they do not hold rights regarding private properties: shopping centres, gasoline stations and workplaces; municipalities can rather say what should not be built there and rarely what should be built there.

- Municipalities enter into contact with Better Place/CLEVER when a private person or a company request a new charging facility. Their role is to give Better Place/CLEVER an overview of the situation and direct companies' interest into the specific area. Municipalities also bring into contact Better Place/CLEVER with an interested party.
- Before whole the procedure of issuing permissions starts, municipalities check preliminary if the charging infrastructure location is possible on properties which Better Place/CLEVER pointed out as being of interest.

- Also Better Place/CLEVER is provided with detailed maps of the specific properties and of the local plans, which cover the location of the possible charging infrastructure. Hence, they can also asses by themselves if there is a point in starting the application process for a specific property.
- Before the procedure of issuing permissions starts, municipalities try to arrange a meeting with all the authorities issuing respective permits, such as fire brigade, police, traffic planning department, local citizens' representative. Therefore, they don't have to go from one office to another, asking which documents are required since everything is established at the same time. Afterwards, Better Place has to send all the required documents and they have already here an overview if they get all the permissions or not, as after the meeting they know what exactly can be an obstacle.
- There is only one permit issued by municipalities which companies need to apply for while setting up a construction in Denmark: it is building permit. The process of issuing the rest of the permits needed starts automatically when application for a building permit is made.
- The BSS can be physically set up before all the permissions are issued. It is possible, but only after all the technical documentation of the building is provided and preliminary decision of compliance with local plan is given. However, if it occurs that some requirements are not met and the building permit cannot be issued, then Better Place has to stop construction without borne costs' compensation.
- Not only the physical set up of the BSS can start before building permit is obtained, but municipality also endeavours to ensure that the threat of building permit refusal is low. Municipality looks for possible dispensation, if there appear obstacles concerning local plan compliance.
- In some places, there are already standing signs directing to BSSs, namely "Batteriskiftestation". Road authorities agreed to put these signs on the roads, despite of the fact, that the common sign "Battery Swap Station" is not approved yet for the whole European Union[2].
- In some municipalities Better Place does not pay for renting/using the land if the CP is located on public property.

Indirect support:

- Legislation supporting EVs: EVs are exempted from the registration tax (180% of car's basic value) and annual tax until the end of 2015. However, when it comes to EVs' purchases made by municipalities, it can occur to be a less convincible incentive, as municipalities already purchase cars (diesel, gasoline fuelled) without paying VAT (25% of car's basic value). Therefore, it can occur to be that EV is more expensive for municipality than this fuelled with traditional fuel resources. Hence, new subsidies for EVs should be provided if municipalities are to bring the e-mobility concept into life. Continuously, it is an important problem as public authorities are these who should spread innovative solutions, and when they do not show a successful example, people will not start using EVs (Dehgan, 2012)

[2] As Denmark is a member of EU, all the signs on roads should be standardized.

- Despite of the fact mentioned above, several Danish municipalities purchase electric vehicles and this way show that they are reliable, secure and cost effective.
- In several cities there is free parking for EVs provided. For instance in Frederiksberg (København) where several free 2-hour parking zone are located for all car users. Must you park in the parking zone for more than 2 hours, you have to purchase a parking license. These P licenses are free for electric cars users. As one of the interviewees said, abolishment of parking fees for EVs will attract more users not only because of decreased EV's utilization costs but also because of facilitating parking activity (no more necessary to spend time on buying tickets, choosing number of parking hours, and thinking each time about time needed).
- In several cities there are implemented Low Emission Zones. These are restricted areas where it is required that diesel trucks and buses over 3 ½ tons are equipped with particle filters that live up to the EURO 4 norms or higher. Approved particle filters intercepts approx. 80% of the particles from a diesel engine (Miljo Zoner, 2012). In relation to electric vehicles, it means that can be beneficial for companies to acquire electric vehicles to their fleet of vehicles as the electric vehicles automatically meets the requirements for driving in the zones.
- Municipalities support charging infrastructure spread through parking spaces management; places can be reserved for charging reasons so that only electric vehicles can park there.
- Advertising renewable energy sources deployment for electricity supply is another way Danish municipalities' support e-mobility spread. This encouragement coming from the local level is supported by the Danish national energy objectives: goal of being 100% fossil fuels independent till 2050 and 50% energy production share from wind energy till 2020 (Danish Government, 2011).

2.4 Summary and conclusion

1. Spread of CPs and BSSs is indirectly but strongly supported by the incentives for EV users provided by the national government, such as registration and annual tax exemption as well as provided by the municipalities, such as free parking places for EV users, low emission zones, EVs use advertising (EVs use by municipalities).
2. Moreover, if EVs are to be an environment friendly vehicle, use of renewable energy for fuelling them must be secured by the national and local authorities. Thus, supporting smart grid and use of wind, solar and other renewable energy resources should be treated as a way of supporting BSSs and CPs and therefore should become even more intense in Denmark.
3. Permissions: the legal process of BSS's set up could be slowed down (the most common reason in Denmark, as mentioned by the interviewee from Randers municipality) by the property sellers, who have special requirements concerning the future usage of their property. Basically, they do not want to have a competitor on the sold land (especially company involved in the same business as the owner of the sold land is; especially important when it comes to companies competing in the geographical

proximity). However, when it comes to BSSs, they are not problematic; they do not create a competition to their neighbours.

4. Permissions: Even though municipalities in general are strongly supporting BSSs establishment, some delays also occurred.
5. There are no financial subsidies for charging infrastructure in place, though the one of EVs purchases is provided. The Danish government ensures that until 2015 neither annual taxation nor purchase-tax is paid for an EV acquirement.

Chapter 3 Charging infrastructure: technical operation and physical setting up process

3.1 A Battery Swap Station: technical operation's description

Battery shift process:

For shifting the battery the driver enters a lane, the car proceeds along the conveyor while the automated switch platform below the vehicle lower the battery from the vehicle. Then the part of the car's bottom where the battery was taken from is cleaned and the charged battery is mounted into the car. The process takes around 3-4 minutes. The system is very simple: inside the station, there are just batteries lying on the shelves, a shuttle taking a battery out from the shelf and putting it onto the robot containing the toolbox, which dismounts the battery and ensures the charged battery's proper location at the bottom of the car.

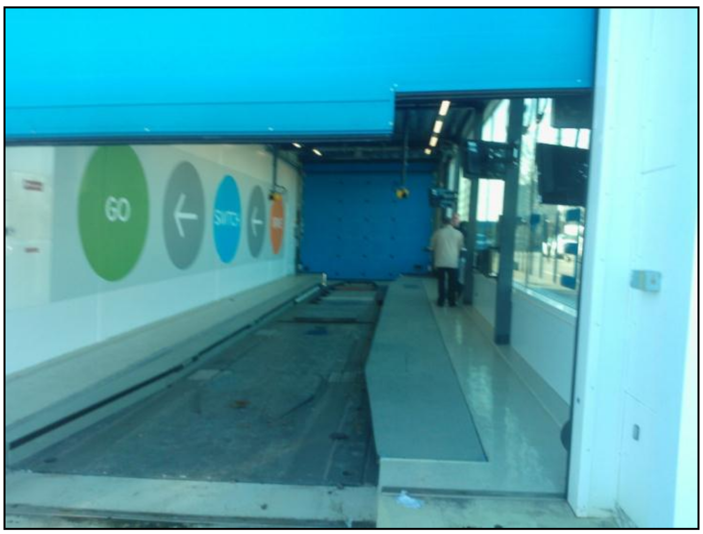


Figure 14 BSS: Switching tunnel interior, source: own materials

If there is new car model/vehicle type (trucks, vans and buses) with other type (shape, size) of removable battery launched to the Danish market, then they can be served by BSS as well, as Michael Salomon from Better Place states. The current robot can serve other types of toolboxes necessary for battery's switch and when it comes to the other private car models, the only retrofit needed will be an additional function of replacing the currently mounted toolbox with the other one and a different shelf system (depending on the battery size and locking mechanism). In case of bigger vehicles, there will be just a need to build a second, higher switching tunnel next to the existing one and add larger shelves for bigger batteries. The BSS system operation is fully automatic: no worker is needed to operate the BSSs. During the first months there are workers there, but their role is just to make the switches more comfortable for first users – so to familiarize them with the system.

Technical problems connected with battery swapping concern mainly a toolbox which remove the used battery and put a new one into the car. When this or other problems occur, customer does not have to call the technical service. The station is monitored by the workers at the operating centre, and when a malfunction comes/ switching takes too long time, then they see which exact part of the switching process takes longer time than normally. If that happens, they call technicians and they log in and connect to the BSS's operation system. They try to fix the problem and if it does not work then they come to the station and fix it there. It will be also visible on Oscar tool, that there is a delay and that they experienced malfunction and have to call the customer advisor. There is always a car behind the BSS so if the driver does not want to wait 30 minutes he can continue the journey. The person's own car will be delivered afterwards to the customer's home.

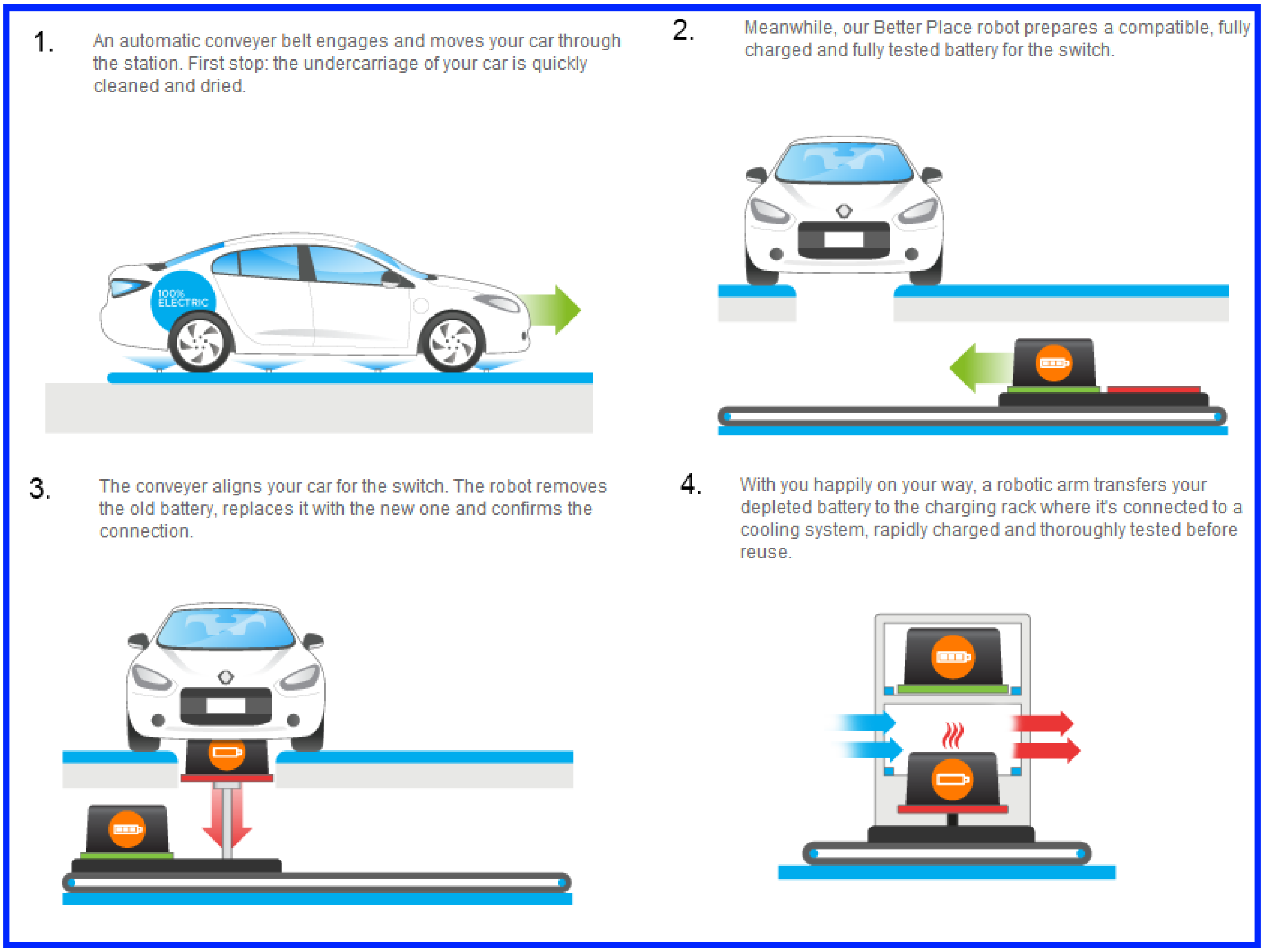


Figure 15 Battery switching process, source: (Better Place, 2012)

Switching and charging time:

Switched battery of Renault Fluence (22 kWh capacity) can be fully recharged within 30-60 minutes, as the power of the charger is 33 kWh (32 Amps; 172 V). Each switch last 3-4 minutes and the capacity of BSS is 12 switches per hour. Currently, the biggest BSS in Denmark, Beta Station Gladsaxe has the capacity for 16 batteries; several have the capacity for 8, which in any case should prove sufficient for the next few years. Most stations have 4 chargers and batteries, lesser used stations like Esbjerg have only 2 as there is currently no customer basis for more. As Michael Salomon from Better Place said, they will be lucky to have 1-2 switches per day this year. Continuously, there is no need for charging time improvements; in the future, when the number of switches will increase, the time can be decreased. But this requires retrofits of the whole system to work faster. The charging time can vary depending on the battery's temperature: if it is very high, then there is time needed to cool it down, before the switch takes place.

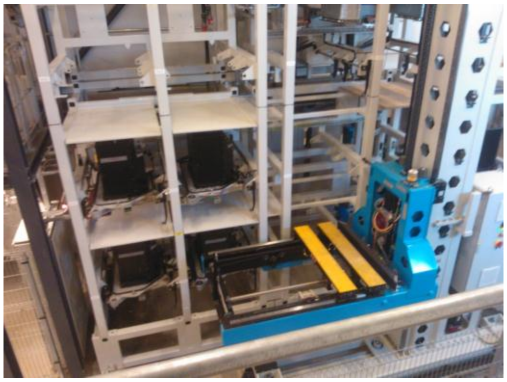


Figure 16 The BSS interior: a charging rack, source: own source

Ev drivers' services

EV is permanently connected to the BSS with the use of the electronic equipment – Oscar tool (tool developed by Better Place and Renault-Nissan). It provides the driver with the following services:

- *directions to the nearest battery switch station or charging stand,*
- *possibility of routing,*
- *information about the scope and planning of the next charging or battery replacement,*
- *warning in case of almost empty battery,*
- *charging and battery replacement - information about the charging process, such as priority handling and charging of battery replacement process* (Better Place, 2012H).

Figure 17 Oscar tool showing the remaining battery's level, source: (Better Place, 2012I)

3.2 A Battery Swap Station: physical place description

- Inside the building there is 1 line and 4 chargers, shelves filled with batteries and the robot taking the used battery out from the car and placing a charged one into the car.
- The capacity of the BSS is for 16 batteries, however the number of batteries differs from BSS to BSS: from 2 to 16 (see above).
- There is a motion detection video surveillance, proximity sensors and laser "walls" installed inside the building to make sure that vehicle is located in the correct position to perform a switch and also in order to ensure that no one enters with the car and at the exit as well.
- 1 lane is leading to the BSS.
- 3 parking places are secured outside of the building.
- Next to the BSS there is located an electric substation (transformer station), which is both distribution substation and a collector substation. It means that energy can not only be transformed to the lower voltage (distribution substation) and used by BSS, but also to a higher voltage (collector substation) and sent back to the grid with low energy losses.

Figure 18 Battery Swap Station building exterior, source: own pictures

3.3 A Battery Swap Station's set up process

Legal issues connected with setting up BSSs' in Denmark are described in chapter 2 of this report, while the whole process of collecting permissions is described in details in chapter 7. Focus of this chapter is therefore put on the missing part of the process: physical setting up of the BSS building, swapping system integration and testing, while the legal side of the course of action is only signalized.

Timing	6 weeks-8 months	2 weeks - 6 months	16 weeks	2weeks	1 week	1 week	OPENING UP
Steps in set up of BSS process	Obtaining permissions	Renting/buying property	BSS's building set up	Machines' integration	Station's integration	Testing	

Figure 19 Setting up process of BSS

Obtaining permissions – The process of BSS set up begins after technology was developed, malfunctions corrected and retrofits made (the whole took Better Place 3.5 years). Firstly, preliminary BSS locations are chosen and permissions for these spots are trying to be obtained. Timing of this stage varies from municipality to municipality: from 6 weeks up to 7-8 months, as experienced in Copenhagen. When the spot is found and Better Place starts negotiation with the municipality, they deliver a comprehensive report on Battery Swap Stations and the person responsible for physical set up of previous BSSs explains potential problematic issues.

Renting/buying property – The average time for renting/buying varies a lot for the BSS: from 2 weeks to 6 month and depends mostly on the owner. Negotiation for a specific lot starts early, before the permissions are obtained. However, property is not acquired before all the permissions are gathered, so it is sure that BSS can be built at the specific spot.

BSS building's set up stage – Time needed to set up BSS after all the permissions are obtained. The overall time needed to put up BSS is 16 weeks, including ground works, plugging in to water, sewage system, electricity and telephone interviews. However, it takes only 2 weeks to construct the very BSS's building. It is because all the machines are built earlier, so the task afterwards is only to erect a simple construction containing that equipment.

Machines' integration stage – machines' integration take 2 more weeks. The first goal is to program the devices to work precisely: place the batteries at the exact part of the car's bottom etc. The second important task within this step are retrofits. Which are needed as the very first machines for BSSs where very simple comparing to what is now.

Station's integration stage – station's integration takes 1-2 weeks, to make sure that all the elements are on the right place – that the software connects to the station and that all of this is up and running. This stage also includes sanity testing.

Testing stage – Malfunctions creation and toolbox integration with a car are the main tasks and most problems occur during this step. An internal requirement is to make 1000 switches with no more than 1 malfunction. Basically malfunctions are collected to ensure that when the problem occurs, there will be enough information gathered to fix the problem quickly. When that is done there are undertaken 1000 switches with each malfunction found, so it means that the process can be prolonged to several thousand switches. And if the malfunction or the machine fail is experienced again, it must of course be tried again; some toolbox errors can take even 9 or 10 tests, before working correctly.

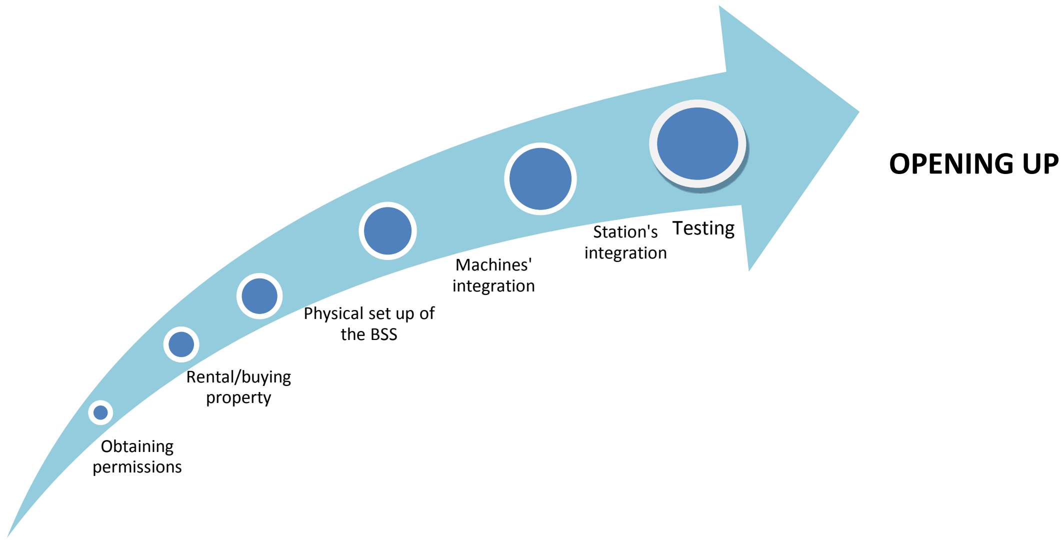


Figure 20 Physical BSS establishment process - main stages, source: own drawing.

3.4 Charging Points and Fast Charging Points technical operation description

The core focus of this report is put on the new solution BSS. Therefore the technical operation details of the charging points in Denmark will be only roughly described.

FCP&CP technical operation description

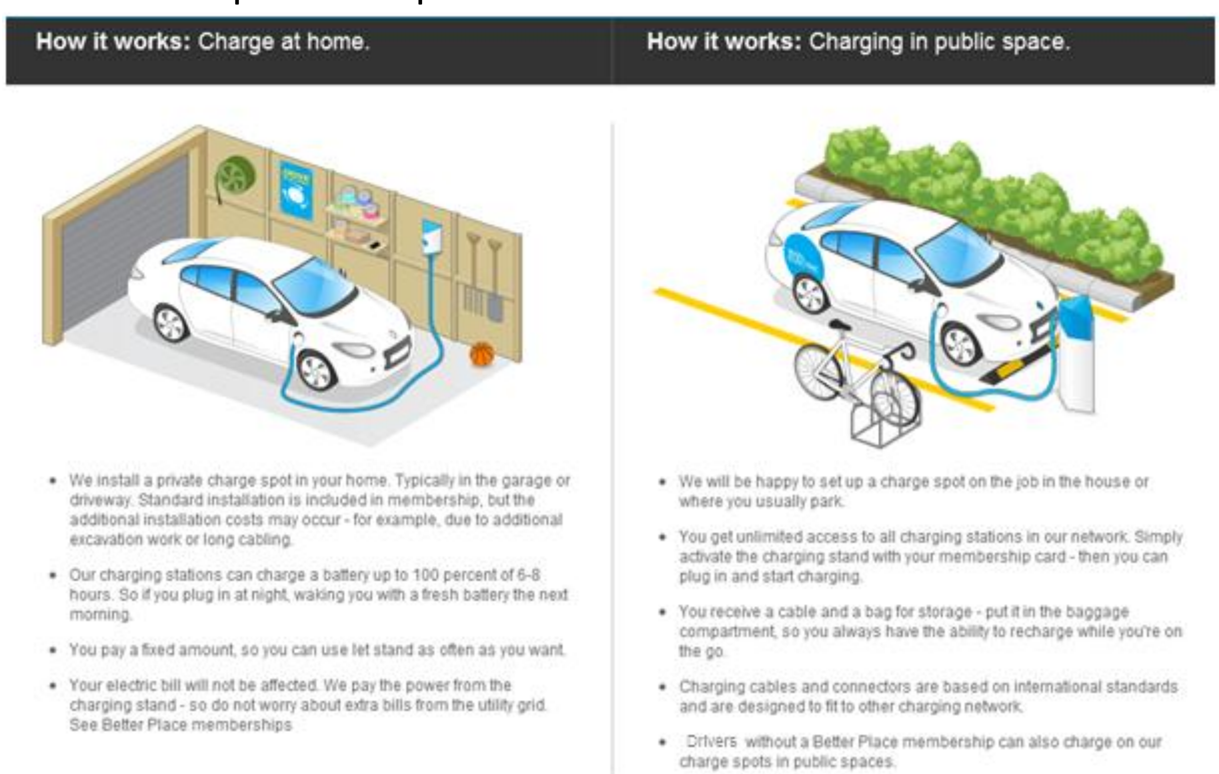


Figure 21 Charging from the home charging station and from the charging spot in public space, source: (Better Place, 2012G)

Charging time and mode

Charging infrastructure for EVs can generally be divided into two: charging points and fast charging points. CPs, both from Better Place and CLEVER, are charged with 16 Amps, within 4-6 hours. Charging vehicles with FCPs can fuel the battery to 80% of capacity within 30 minutes (CLEVER, 2012E). Fast charging could be defined as able to charge a significant amount of energy (25-75% of the battery's capacity) into the battery within 5-15 minutes (EDISON , 2011). For CPs charging mode 2 is used, while for FCP charging mode 3 or 4 (more information can be found for instance at the website: (Schneider Electric, 2010).

Charging infrastructure also differs depending on the intended location: these located at houses and at companies are generally wall-mounted, while these for public spaces are in a form of charging stands.

Figure 22 Types of charging infrastructure available in Denmark, source: (Better Place, CLEVER, 2012E)

The vehicle battery is charged with up to 50 kWh DC power via a plug (22-25 kWh battery, which is a typical one for EVs currently available on the market, can be charged within 20-30 minutes) (CLEVER, 2012D).

Plug type

Type 1 is an IEC 62196-2 plug reflecting the SAE J1772 specification. Type 2 is an IEC 62196-2 Mennekes plug reflecting the VDE-AR-E 2623-2-2 specification (this plug type implementation in Europe is driven by Germany), and type 3 is an IEC 62196-2 plug reflecting EV Plug Alliance specification (this plug type implementation in Europe is driven by France and Italy). Better Place uses plug type 1, so IEC 62196-2 plug reflecting the SAE J1772 specification (Better Place, 2012F). CLEVER uses CHAdeMO standard.

Figure 23 IEC 62196-2 Plug type 3: EV Plug Alliance (EV Plug Aliance, 2012)

Figure 24 IEC 62196-2 Plug type 2: VDE-AR-E 2623-2-2 Mennekes

Chapter 4 Danish experiences in utilization of smart grid for electric vehicles' charging infrastructure

Smart grid refers to *the transformation of the electric power system into an 'energy internet', allowing utilities and customers to share information in real time, often automatically, so that both sides can manage electricity use more effectively* (Copenhagen Cleantech Cluster, 2011).

4.1 Current development stage of the smart grid concept in Denmark

Circumstances for smart grid establishment in Denmark

Comments of Brian Vad Mathiesen from Aalborg University on smart grid can say a lot about the development stage of this solution in Denmark:

"*Denmark is definitely the one country which is furthest advanced with regard to a smart grid. The main reason is that we already know how to handle the integration of a large amount of wind energy – which no one else does".*

"We already have parts of the solution: a flexible market, a district heating system, massive amounts of heat pumps, and a lot of activity within the smart grid sector" (Copenhagen Cleantech Cluster Hub, 2011)

Renewable resources, especially wind are already today a widely used energy source in Denmark. Renewable resources accounted in 2010 for 33 % of electricity produced in Denmark, where wind alone accounted in 2011 for a 28% share (Ministry of Climate, Energy and Building, 2012) . It is estimated, that up to 75% of energy can be supplied from wind in the future if smart grid is deployed countrywide (Copenhagen Cleantech Cluster, 2011).

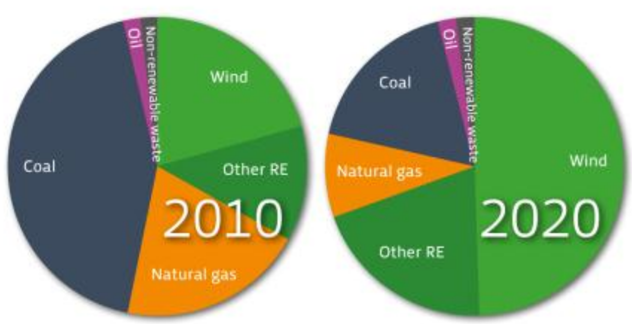


Figure 25 Share of renewable energy in the energy consumption in Denmark,source: (Ministry of Climate, Energy and Building, 2012)

According to IBM estimations, 170 billion kilowatt hours are wasted yearly because of inefficient energy consumption (Ministry of Foreign Affairs of Denmark , 2011). A big share of these loses is connected with energy production from windmills, which often produce excess power at times with low energy consumption. Therefore smart grid development and its connection with EVs, which can serve as energy storage, is so important in Denmark.

In order to implement a smart grid countrywide in Denmark, substantial investments are needed. It is estimated that at least 1,32 billion EUR will be needed till 2025 in order to finance the necessary investments such as system software for controlling the grid, monitoring of the distribution grid, intelligent system for the end user and the upgrading of the metering infrastructure[3]. However, when it comes to the necessary traditional grid extension and maintenance till 2025 (distribution network extension in order to keep the grid stable in the growing demand conditions), cost is comparable: 1,03 billion Euro (Copenhagen Cleantech Cluster, 2011).

3 phases of smart grid development in Denmark

Smart grid development in Denmark is based on its integration with charging infrastructure for EVs, but also with electric heat pumps and district heating, as can be learned from the chart presented below:

Stages	**First commercial launch of EVs and hybrid vehicles**	**EVs and hybrid vehicles sales start**	**EVs and hybrid vehicles are widespread**
Societal development	1. Electric heat pumps replace increasingly oil and automatic stoker heating solution within the districts where district heating and heating with natural gas is not present. 2.First EVs and plug-in hybrid vehicles are launched to the market.	1. Electric heat pumps are on the way to become widespread heating solution within the districts where district heating and heating with natural gas is not present. However, it is not decided yet what share of electric heat pumps installed will be	1. Electric heat pumps are a widespread heating solution within the districts where district heating and heating with natural gas is not present. 2.EVs and hybrid vehicles are widespread.

[3] Metering today are only remote read meters, and not “intelligent” ones. They enable hourly billing of the energy, but they do not send this information back to the energy supplier.

		accompanied with energy storage facility and aggregators installment. 2. Slow expansion of EVs and plug-in hybrid vehicles sales[4]	
Key activities	1.Communication protocols development 2.Defining roles and responsibility of network operators and commercial actors 3.Adaptation of necessary legal and economic regulations 4. Technical solutions testing 5. Development of tariffs model which would counteract overloading of the distribution network	1. Collection of national and international experiences 2. Building smart grid market mechanism such as trading system benefits and tariffs 3. Technical solutions authorization 4. First wave of commercial smart grid – market penetration 5. Regulations adjustment	1.Commercial deployment of smart grid based solutions with electric heat pumps and/or with EVs and hybrid vehicles 2. Flexible electricity consuming devices widely used among customers 3. Continuous adjustment of market rules and regulations to ensure optimum smart grid functionality

Figure 26 Stages of smart grid implementation in Denmark (Energinet.dk, 2010)

According to Dong Energy, technology for integration of smart grid with charging infrastructure for EVs is sufficiently developed by Better Place and other operators; problem comes at the demand side. Obstacles are especially significant regarding individual consumers – according to Dong Energy smart grid is not to be quickly spread among them, especially when it comes to the home charging stations. It is because the potential profit is too small compared to the effort needed to deploy a smart grid, i.e. charging EVs when it is profitable (lower electricity prices during nights, during off-peak hours) (Hedevang, 2012). Moreover, cost of hourly billing system operation is high.

4.2 Integration of EVs with a smart grid

EVs together with smart grid can give a higher effectiveness of energy use, first and foremost because EVs can be charged during nights (while used during days thanks to the batteries serving as energy storage) when a production of a significant excess energy takes place. This increased flexibility of electricity consumption management is especially helpful in regards to renewable energy sources such as wind: *"Electricity companies with a lot of wind turbines in their network have at windy times even been forced to administer negative prices, subsidizing use of electricity (as happened recently in the north of Germany and in Canada). In short: the growth of wind energy, solar power, tidal generators and other decentralized sources of electricity raises problems for*

[4] EV's are only so flexible to the Danish energy system that the owner allows them to be. Meaning: Only if the customers perceive the benefits of the smart energy usage, EV's will be positive to the Danish energy system. In the other case all EV's will be charged when people come home from work at 16-18, in the peak period, and finish around 20-22, without any synergy to wind energy. Moreover, if charging is performed during peak hours it will further overwhelm the energetic grid, causing that extra grid reinforcement have to be done.

the companies that distribute electricity, making it even more complicated to keep the balance in electricity networks that are less controllable” (E-harbour electric, 2011). Secondly, energy storing in batteries of EVs, gives an opportunity to send it back to grid in peak hours, thus to overcome problem of lack of stability of energy supply from renewable resources. However, before sending energy back from EVs to grid can be implemented, it is needed to take a preceding action: implement further differentiation of energy prices depending on the day-time when charging is performed (peak/off-peak hours) and taxes on energy (depending on the overall balance of energy consumed plus sent back to grid); this can respectively encourage EV users to charge during off-peak hours and send energy back to grid. Undertaking these actions is needed, as according to Dong Energy, current profits coming with the smart energy management are even lower than the price of hourly billing system installation and operation.

Smart grid integration pilot project on Bornholm

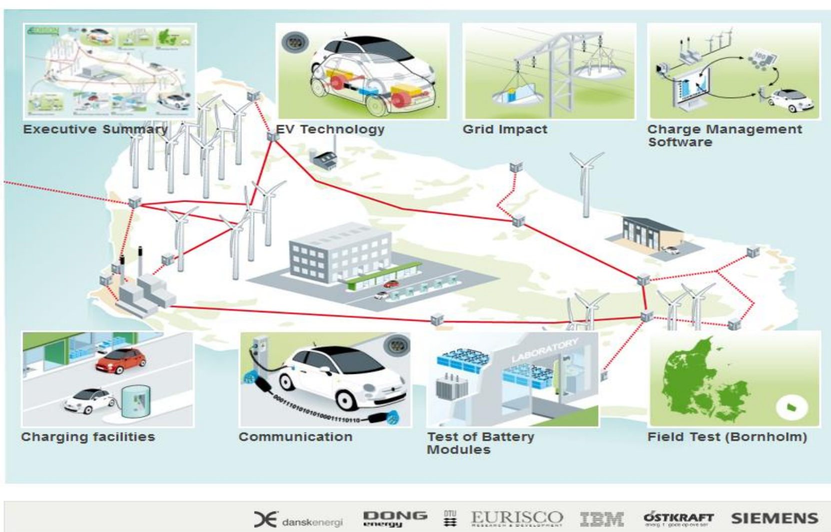


Figure 27 EDISON consortium simulation of smart grid integrated with EVs source: (EDISON , 2012)

Project received in 2011 further fundings, and from that time pilot tests were extended to test not only smart grid integration with EVS but also with heat pumps, dishwashers and electric water heaters. New project is called ECOgrid EU (IBM, 2012).

EDISON consortium consists of: Dansk Energi, Dong Energy, Eurisco. Research and Development, IBM, Østkraft, Siemens. 50 electric vehicles were installed on the island of Bornholm as storage batteries for excess wind energy on the grid. When the wind blew the cars charged, when the wind died down, the cars provided extra capacity to the grid. More information are available at www.edison.dk

Thirdly, charging infrastructure for EVs is equipped in the communication technology enabling up-to-date information on its exact energy needs for the energy supplier, thus managing the energy flow effectively: buying the exact amounts needed and selling energy back to a grid whenever possible, so that the excess energy resources are always in use.

On the other hand*, as EVs increase use of electricity, they can occur to be a heavy drain on the grid at times* (COPENHAGEN CLEANTECH CLUSTER, 2011). Therefore, firstly, either traditional grid should be extended, or smart grid should be implemented. Costs of undertaking these actions are comparable in Denmark, but the latter gives an important “side effect”: it enables a more efficient use of renewable energy resources. Secondly, the legal and the financial support for the “green EVs” should be higher than this for the “black EVs” (EVS which do not use renewable energy for charging). It is because only the “green EVs’” construction (cheap enabling EV’s communication with a smart grid is built into the car) enables them to use the smart grid, so that they are not only able to charge the battery but also to give the energy back to grid, what would decrease a negative impact on the electric network created by EVs.

Benefits linked to integration of smart grid with EVs

Below there are presented benefits associated with smart grid integration with EVs, both for EV users and energy suppliers:

a) Benefits for energy supplier:

- **Grid stabilization** is secured by both V2G and V2H solutions, as shown in the pictures below. Moreover, “*by systematically avoiding grid congestion, it may be possible to avoid expensive upgrades to the transmission or distribution infrastructure*” (IBM, 2012). However, substantial costs of smart grid implementation must also be taken into account.

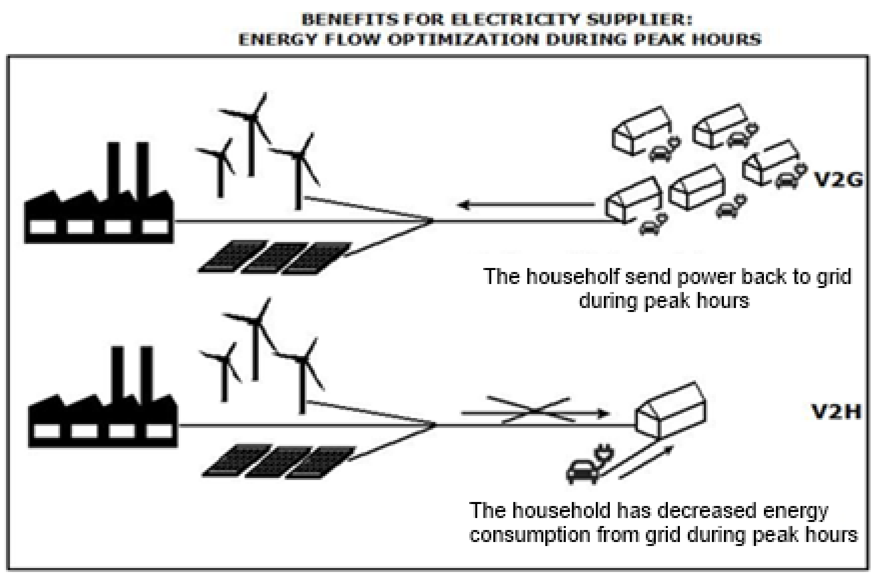


Figure 28 Benefits for electricity supplier from EVs and smart grid integration, own drawing

- EVs together with smart grid give also an opportunity to **lower expenses connected with grid stabilization**, since they can serve as cheap energy storage. Physically, there exist another solution for correcting energy supply imbalances, but it requires an additional huge cost for the energy producers: big energy consumers already provide an increase/decrease of their energy demand according to energy producers’ request, but the cost of these services is high in Denmark. “*Some calculations show that more* *than 10 percent of the total electricity bill paid by end users is connected to imbalance"* (E-harbour electric Project, 2011).

b) Benefits for EV users

- EV users can benefit from the **lower energy price** (V2G solution), since EVs can be charged during night when then energy is cheap and sell the energy back to the grid during day (peak hours mainly), when energy is expensive (peak hours, when the minority of EVs are charged). If the energy is produced from windmills, then also another condition, regarding the time of buying and selling energy, should be considered for EV users. When the wind is strong energy should be bought, because the price of energy produced is low, while when the wind is weak energy should be sold, because the price of energy produced is high. Though, these benefits are only potential, not existing yet.
- Vehicle can become energy supplier for the building (V2H solution), serving as a partial **security in case of blackouts**. Currently a fully charged EV's battery is able to keep a family functioning for 2 days without grid connection (22 kW battery and daily average electricity consumption in Denmark 10 kWh).

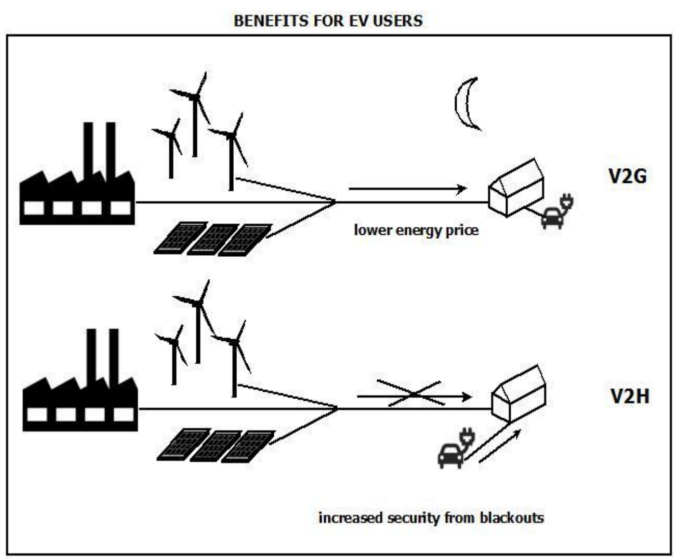


Figure 29 Benefits for EV users from EVs and smart grid integration, own drawing.

Both advantages described above, "benefits for electric car users" and "benefits for energy suppliers", should be considered by public authorities: smart grid stabilization and possibility of renewable resources deployment for a large scale, respectively.

Communication technology between EVs, charging infrastructure and the smart grid

The thing which enables communication between charging infrastructure and the grid is the onboard control unit which communicates with the BSSs, home charging stations and public charging points in a real time (*Oscar, Electric Vehicle Modeling*). Below, a picture of Oscar's interface (more information about this tool can be found in the preceding chapter).

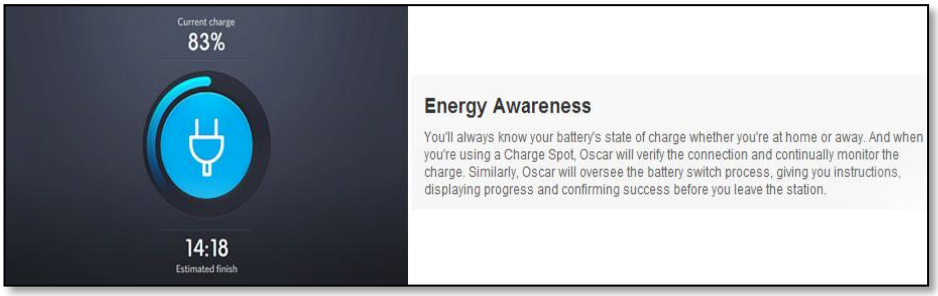


Figure 30 Oscar tool, source: (Better Place, 2012K)

A charging plan shows up-to-date charging needs, which are send from BSS, public charging points and home based charging stations to the energy supplier. It is communicated between Better Place and Dong Energy, what provides a real time information on energy needs between energy supplier, EVs and Better Place. The Oscar tool is an additional tool increasing reliability of a charging plan which, among others, helps to maximize efficiency of energy use at Battery Swap Stations. Oscar informs Better Place's communication center that EV is going to be charged at the BSS so that a fully charged battery can be prepared.

Below is presented an illustration showing communication technology used by Better Place and Dong Energy (the largest energy supplier in Denmark):

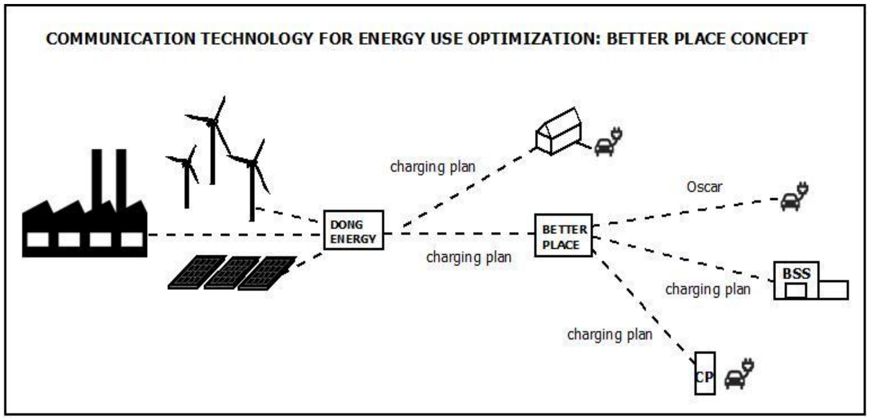


Figure 31 Communication between EVs, charging infrastructure and smart grid, own drawing.

4.3 BSS and smart grid integration in Denmark

Given current demand for Battery Swap Stations' and Charging Points', there will be no problem of grid overwhelming, as batteries will be charged during nights/ off-peak hours, when excess energy is available. However, this situation will change when more and more EVs appear on roads, since many daily charging of batteries will have to take place; energy consumption will become even higher when electric trucks are launched. Batteries will have to be charged during peak hours, what will cause overwhelming of the grid. However, BSS can help to decrease this impact, as batteries at BSS can be charged during off-peak hours and wait charged for EVs coming during peak hours. Moreover, BSSs can supply grid with power, when production from power stations, wind turbines or running CHP stations is low, as shown in figure 32.

BSSs are plugged into smart grid. The communication solution has been developed in cooperation with Dong Energy. The battery can be charged within an hour, but the charging time will be adjusted to smart grid needs, and therefore charging time will in most cases take 3-4 hours.

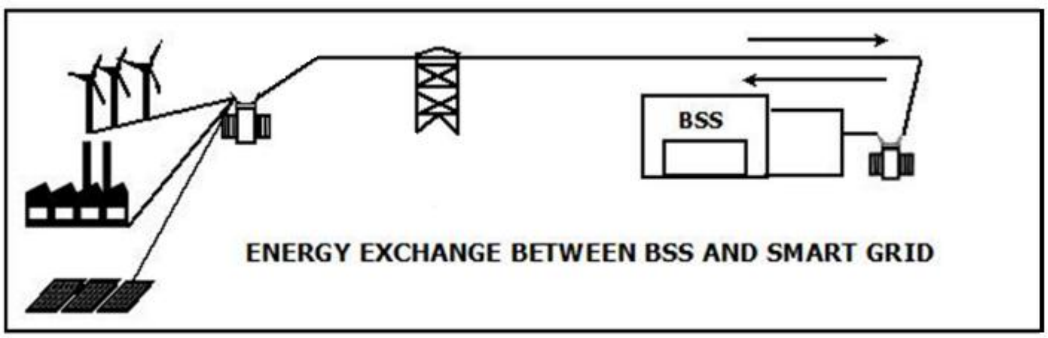


Figure 32 Energy exchange between BSS and smart grid, own drawing

During an interview with Dong Energy it was found, that customers might be more willing to start using V2G and V2H solution if they do not bear the cost of the decreased batteries' life time. This can be ensured for BSS users, as the discharged batteries will be replaced with new ones by Better Place, each time entering the BSSs (drivers of EVs with a switchable battery do not own the batteries; they pay a monthly subscription covering they usage). This way, also car manufacturers will not be against EVs integration with smart grid, since the decreased lifetime of the battery (due to frequent charging and discharging of the battery) will not be known by EV drivers, but only by the BSS operator.

BSS is not on its own an important element of smart grid, as energy consumption by all the 20 BSSs per year is around 8 GWh[5], while the overall grid capacity in Denmark is 34 451 GWh (per year). Conversely, smart grid is

[5] Counting 6 charging cycles per 24 hours (charging takes minimum 4 hours) performed at 8 chargers at 20 BSS stations. This is a maximum energy consumption.

important for BSS profitability, as Better Place will be paid for energy supplies back to the grid, and the fact that BSS has a higher charging scheduling flexibility than charging points.

Summary

- EVs play a crucial role in increasing the use of electricity as a power source. It is beneficial for the environment as a big part of electricity in Denmark is produced from renewable energy resources. If the current overall capacity of windmill plants is taken into account (4 052 MW), it can be noticed that only a big number of EVs can cause a significant rise in a share of energy consumed from windmill plants.
- EVs used for energy storage increase efficiency of energy usage, since excess energy produced can be collected in batteries during nights (off-peak hours), but consumed during the days (peak-hours).
- As EVs increase use of electricity they can occur to be a heavy drain on the grid at times where a smart grid solution is not used by the charging infrastructure.
- Fortunately, implementation of the smart grid solution is already used by multiple charging spots and BSSs. It can systematically avoid grid congestion thus may make it possible to avoid expensive upgrades of the transmission and distribution infrastructure.
- On the other hand forecasts for smart grid use by individual consumers are not optimistic. According to Dong Energy smart grid is not to be quickly spread among individual consumers, including its deployment for the EVs' home charging stations. It is because a potential profit is too small compared to the effort needed to use smart grid: charging EV when it is profitable.
- Costs of traditional grid extension and introducing smart grid are comparable, but still the latter gives an important benefit: it enables efficient use of renewable energy sources and allows savings on grid stabilization.
- BSSs are not an important element of smart grid on their own and they are not playing a leading role in this solution spread as the energy consumption by BSS is not that significant. However, smart grid is important for BSS profitability, as their owner will be paid for energy supplies back to the grid.
- Electric vehicles communicate with the BSS in real time using the Oscar tool. Hence, the BSS can easily plan its energy needs thus manage the energy possessed effectively: buy the exactly needed amounts and sell the energy back to the grid whenever possible, so that excess energy resources are always in use.

Chapter 5 Current development stage of the Battery Swap Stations and Charging Points in Denmark

5.1 Charging infrastructure in Denmark

Battery Swap Stations

Better Place managed to reach its goals of establishing all 17 BSSs in Denmark and put them into operation. They are located mainly along the highways E20 and E45: from Copenhagen to Esbjerg and from Skagen to the German border. The first station was opened on 25th of June 2012 in Gladsaxe (Copenhagen outskirts, at the intersection of Hillerødmotorvejen and Motorring 3 highway). Next to open within the following months are BSSs in Køge (9th of August 2012), Vejle and Slagelse. Better Place announced that there will be all 20 BSSs operating till the end of 2012. As was learned during the interview with Better Place, they are planning to plug in BSSs to smart grid and start using its advantages as soon as the system will become fully operational – the BSSs network will be in place. They have already created, together with Dong Energy, the biggest energy provider in Denmark, a system enabling smart grid deployment at BSSs. However, in January 2013, Dong Energy decided to stop financial investments to Better Place Denmark. This decision was accompanied with other cut-downs on the new development projects of Dong Energy performed by a new CEO of Dong Energy. Though, the already invested 200 million DKK will stay in Better Place Denmark consortium (CSR, 2012).

Figure 33 Better Place's Battery Swap Stations and CLEVER's Quick Charging Points location in Denmark, source: own drawing on the basis of (Better Place 2012A).

Charging Points and Fast Charging Points

Better Place is not only forerunner when it comes to BSSs but also when it comes to CPs in Denmark; they have already established 500 public charging points and 300 for enterprise (Better Place, 2012B). In Copenhagen they are operating 50 CPs. There are no FCPs planned by Better Place, while Clever, another important Danish operator of charging infrastructure, has already installed 45 CP and 25 FCP. They are not focusing on BSSs and are planning to open 56 FCP till the end of 2012 (Better Place, 2012C). CLEVER aspires to have in place 150 FCP and 700 regular public/ semi public (for enterprises) charging points in 2 years (CLEVER, 2012B).

Figure 34 Better Place's public charging points location in Denmark, source: (Better Place, 2012C).

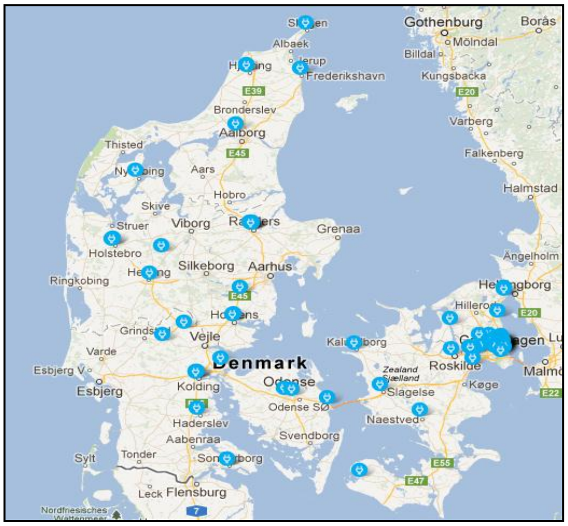
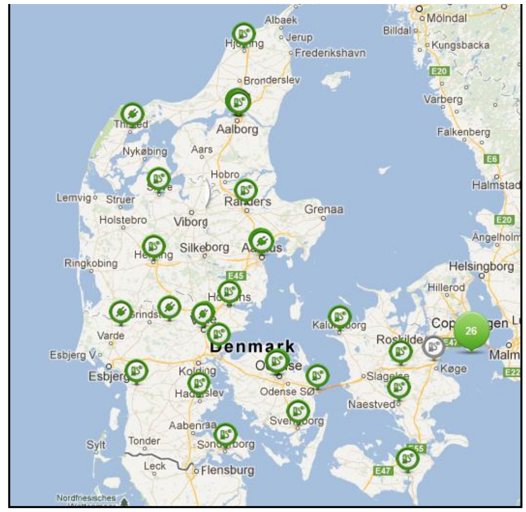


Figure 35 CLEVER's charging points and fast charging points location in Denmark, source: (CLEVER, 2012C).



Electric vehicles

In general, EVS can currently compete with gasoline or diesel fuelled cars when it comes to the travelling comfort and the price. As shown in the tables on next page, the basic technical operation details are comparable. Renault Fluence is the only model with switchable battery available in Denmark. The battery for Renault Fluence costs 75-85 000 DKK, but with the current business structure the battery is rented from Better Place, meaning that the price without the battery is DKK 205 000 DKK. So the cost of the (NSR, 2012) battery is about 1/3 of the price. Hence, cars designed for removable batteries are much cheaper, as they are sold without the battery; their use is secured within the Better Place membership (monthly payment).

Figure 36 Renault Fluence inside BSS, source: (Green Carre Ports, 2012A)

Renault Fluence can currently be purchased in 20 Danish cities (May 2012). There are several EVs with mounted battery available on the market, and more are coming. The most well known are: Renault Kangoo, Renault Zoe, Nissan Leaf, Peugeot iOn, Mitsubishi iMiEV, Toyota Prius, Citroen C-Zero, Citroen C1 Electric, Tesla Roadster, Tesla S, Ford Transit Connect, Iveco Daily and Peugeot Partner Van Electric (Better Place, 2012D) and many more are on their way. There were sold 170 Renault Fluence in total (data from September 2012) and 975 electric personal vehicles in general (data from June 2012). Whole fleet of electric vehicles in Denmark is 1 160 items (data from June 2012).

	Renault Fluence ZE	Megane Sports Tourer Diesel
Price	206.900 DKK	248.900 DKK
Total price (DKK/km)	3.44	4.08
Maximum range (km)	130	1200-1500
Average energy use	140 Wh/km	20.8-27.8 km/l
Max power kW (hp)	70 (96 hp)	66 (90 hp)
Top speed (km/h)	135	180
Accelaration 0-100 km/h (secs)	13.40	12.90
Dimensions (mm): length, width, height	4748, 1813, 1458	4567, 1804, 1507
Number of seats	5	5
Trunk's capacity	317 l	524 l (min)
CO2 emission (g/km)	0	104

Figure 37 Comparison of Renault Fluence ZE and Megane Sports Tourer basic technical operation details, source: (Renault, 2012A), (Better Place, 2012D).

EVs with switchable battery account for a small share of the market. There are currently 170 switchable battery personal EVs on roads comparing with 805 mounted battery personal EVs which makes 17% of the personal EVs sales. However, this disproportion is not that relevant, if the time of appearance of both EV types on the market and charging infrastructure is considered. The majority of mounted battery EVs where purchased within the last 3-4 years (879 EVs out from 975 overall EVs number), while these 170 switchable battery EVs were sold within less than a year. Still the sales number is below expectations.

5.2 Quick charging points and Battery Swap Stations feasibility

In Denmark, as in other NSR countries there can be found fast charging infrastructure. In Denmark the fast charging infrastructure is operated by CLEVER. CLEVER's Quick Charging Point (QCP) solution is a competing solution to Better Place's BSS, hence it was found important to signalize the issue within this report. Below, can be found figure comparing BSSs and QCPs features. It describes advantages of both solutions regarding issues such as: charging time, costs of set up, comparison of EV's with mounted and removable battery prices, impact on the grid stability, permissions needed, and feasibility for private cars and for freight transport.

BSS

- More feasible solution for trucks and vans as the time of charging their large batteries at FCP would be much longer.
- BSSs are currently the only charging equipment located outside the cities, and therefore the only enabling travels for long distances (between cities). Even if QCPs were put on highways they would not be feasible for long distance
- Lower cost of the car (as sold without the battery) - it can cause high demand on the cars with switchable battery.
- There is no time needed for battery cooling before charging as the new one, waitng at BSS is charged. At FCP it is necessary either to wait until the battery's temperature decreases or to charge longer, as the higher temperature the lower
- Better opportunity for those living in blocks of flats, where home charging stations' location is limited due to space limitations. Therefore queuing at public FCP, as the charging time takes 20-30 minutes. With BSS there is no need to wait so long.
- BSSs seem to be a more environment friendly option than FCPs, since they enable extensive use of EVs – driving for long distances. Hence, EVs will not be used only as an additional mean of transport – mainly in cities, to avoid congestion charging, but also during longer trips. FCPs cannot ensure this, as the charging time takes 20-30 minutes.

QCP

- Standardization of the batteries is not required, but only of power connectors.
- Future development opportunities: it is possible to develop a much faster charging ; it is already technically possible to charge 80 % capacity , within 20 minutes. However, currently it takes 20-30 minutes to charge 80% of capacity at the QCP operating in Denmark.
- Majority of car manufacturers are currently launching cars without switchable battery, so there is a bigger variety of models available. Renault 's market share in Denmark is currently less than 5%.
- Lower cost of the membership, as it does not include significant expenses connected with BSSs utilization (compare: http://www.clever.dk/produkter/abonnement/ http://danmark.betterplace.com/priser/privatperson/
- Lower cost of FCP than BSS establishment, since BSS costs 10 times more than FCP (Interview with Michael Salamon)
- It is easier to find a location for it, it is allowed in more places as it is of small size and no batteries are stored there so the risk of fire is lower.

Figure 38 Comparison of FCP and BSS, source: own elaboration with the use of: (EDISON consortium, 2012) (Peak Energy , 2012) , (World Nuclear Association, 2012), (Wikipedia, 2012) (Better Place, 2012)

Summing up, the current main advantage of battery swapping over fast charging is that charging time is still lower, also in regards to personal EVs. Furthermore, BSSs support grid stability, conversely to charging points. On the other hand, an important advantage of fast charging over battery swapping is the cost of setting up BSS: it is 10 times higher. Additionally, as the batteries’ technology develops quickly, the charging time at QCPs can in the near future become as short as the battery swap.

Chapter 6 SWOT Analysis of Battery Swap Stations

This chapter presents strengths, weaknesses, opportunities and challenges of Battery Swap Station network in Denmark. It does not analyze the impact of BSS but rather try to assess chances for successful BSS spread while providing with its performance description.

Strengths:

- **BSSs technology is developed and 17 BSSs are already operating**; distributed among whole the Denmark.
- **smart grid solution is already used by BSSs**; Better Place cooperate with Dong Energy the biggest energy producer in Denmark, producing 14.5 % of energy from wind power (Dong Energy, 2012A). An extended use of smart grid by BSSs is sure, as **the use of smart grid is profitable for BSS**: charging batteries during off-peak hours and selling during peak hours ensure an additional income (more information: chapter 4).
- BSSs are not directly polluting the environment (more information: chapter 2).
- As BSSs use the energy from smart grid (where wind plants are going to produce a big share of the energy), there is a great chance that **the produced indirect pollution will be low and in the future BSSs will become indifferent for the environment** (more information: chapter 4).
- As BSSs are not harmful for the environment**, it relatively does not take a lot of time to get permissions and start their operation** (more information: chapter 2).
- BSSs are environmentally friendly: after investigation, it was found that BSSs don't generate a significant noise level, as electric cars do not produce it so. The only issue is fire threat connected with batteries (lithium-ion batteries).
- BSSs are well technically prepared for smooth clients' serving (for instance the Oscar on board ICT tool: enables communication between BSSs and the car).
- BSSs utilization costs are not borne each swapping-time, there is a monthly subscription. This situation can be treated both as an advantage and as a disadvantage. Though, it seems to be that **BSS monthly subscription is a more environment friendly option**.

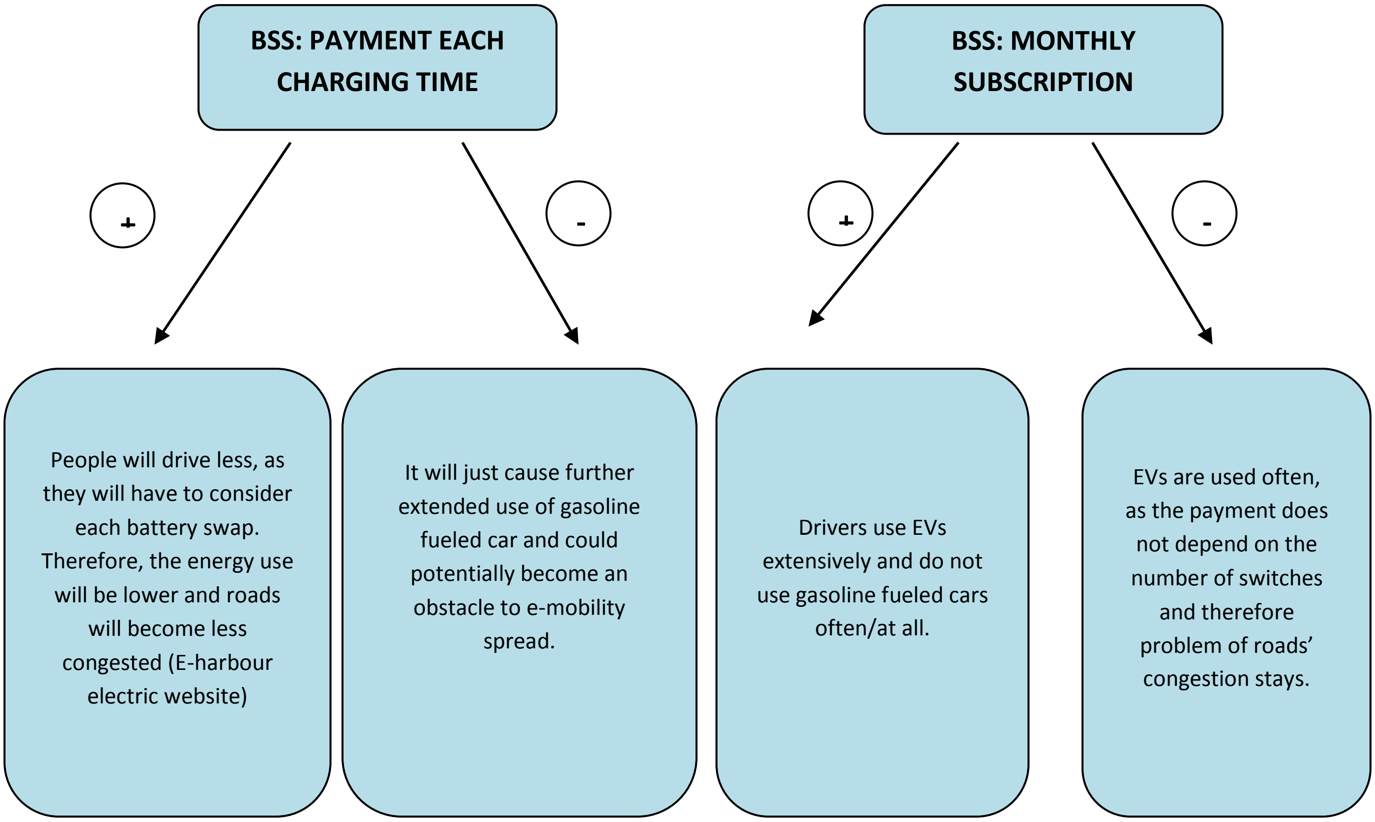


Figure 39 Comparison of two payment systems for BSS use, source: own elaboration.

Weaknesses:

- It is not a tested solution, BSSs are operating only from June 2012 and all already set up BSSs have to serve only 198 EVs (number of Renault Fluence on Danish roads).
- The initial cost of an EV is higher than of the ICE vehicle. Though, according to Better Place calculations, **a total cost of EV use is lower** (including use of BSSs, CPs and home charging stations):

Vehicle	 Renault Fluence ZE Dynamique Incl. metallic paint and live. Cost	Renault Megane Sport Tourer Incl. metallic paint and live. Cost
The car's price	223,480	219,000
Membership / fuel (per year)	25,239 kr. year 20,000 km per. year	12,332 kr. year 20,000 km per year
Financing	43,922	71,043
Variable costs	17,275	25,928
Total Costs (per km.)	4.32 kr. km.	5.47 per. km.

Figure 40 Comparison of the total cost of EV and gasoline fueled car use, source: (Better Place, 2012D)

- **EVs with switchable battery account for a small share of the market uptake**. There are currently 192 switchable battery personal EVs on roads compared with 805 mounted battery personal EVs and that gives Renault Fluence a market share for personal EVs of 17% of sale. However, this disproportion is not that relevant information, if the time of appearance of both EV types on the market and charging infrastructure is considered. The majority of mounted battery EVs where purchased within the last 3-4 years (879 EVs out from 975 overall EVs number), while these 170 switchable battery EVs were sold within less than a year. Moreover, till June 2012 no BSS was in place so buying switchable battery EVs was not of an advantage. To sum up it seems to be that EVs with switchable battery are not of a less interest than these with mounted battery.
- **EVs with switchable batteries cannot be charged at the QCPs**. It is not a technological problem, but connected with competition of charging infrastructure operators. Cars with switchable batteries cannot be charged with the use of QCPs, as Better Place is a competitor for CLEVER: Better Place owns and operates charging spots and BSSs, while CLEVER CPs & QCPs. Although, this problem seems to be more a problem for mounted battery-EVs drivers than for switchable battery-EVs drivers, since the firsts cannot use BSS – they cannot drive for longer distances.
- **Cost of BSS set up is high**: it is the same as 750 CPs, or 10 QCPs.

- A threat is that a significantly discharged battery will be placed in a car after a battery swap. Tesla, EVS manufacturer proposal is that *battery packs can be dropped off at a switching station and swapped for a fresh battery pack when you leave on your trip, and you can pick up your original pack when you return. With this alternate setup; Tesla is hoping to solve the potential problem of dropping off a 1-year-old battery pack only to be given a 3-year-old battery pack in its place* (Peak Energy, 2012). This problem actually does not exist, as **batteries are removed from the use at the BSSs when their capacity diminishes below 80%**. Furthermore, it is not possible to be cheated regarding the battery's capacity: Oscar/other tool used for car communication with CPs and BSSs, shows the range left and the current state of a battery.
- It could look like as a threat of extensive waste production, that EVs' batteries should be changed often, since the partly discharged batteries are withdrawn in order to keep the long range available (it is removed from BSSs when its capacity is permanently discharged to 80% of its capacity). Though, **the batteries are not sent to landfill, but have a second life as energy storage**, at companies eager to use the smart grid benefits (benefits described in chapter 4). There are some companies in Denmark who already asked Better Place if they can buy partly used batteries: several electricity companies and IKEA. Afterwards, they will be recycled by these companies. When it comes to EVs with mounted batteries, not using BSSs, then Renault has already signed an agreement with a company specialized in batteries' recycling.
- Standardization of the batteries' technology seems to be a more feasible solution than **car manufacturers developing new toolboxes for each particular vehicle's model** (with a specific battery type), as proposed by Better Place.
- **Battery's capacity should be larger**. This issue concerns especially larger vehicles, since the batteries are still too small to meet the demand of the companies focusing on the long haulage. Secondly, when it comes to personal cars, the larger battery would undoubtedly increase interest in EVs as well. However, as the current battery's size is already large, it will be hard to put larger ones, if the length, width or height of the car would have to be increased.

Opportunities

- BSSs are feasible for inhabitants fro blocks of apartments'. BSSs should be placed in cities to ensure that people who do not have possibility of using home charging stations (blocks of flats, few parking places which therefore cannot be reserved for charging reasons) can charge on their way to/from work.
- EVs with switchable batteries are more feasible for those commuting for longer distance per day: battery can be switched on the way.
- Battery Swap Stations can be located next to resting areas: being clustered with gasoline stations, hotels and shops.

Threats

- Decrease of driving freedom coming with an electric drive cannot be fought by simply adding more BSSs, as they are too expensive to locate densely throughout the whole country. People will not agree for electric car use if charging infrastructure is not easily accessible or EV's range is small. They will not choose cars which limit them in choice of vacations' destinations etc. Range of an EV must increase, this is for sure. "When the new battery is loaded than you can start to think about where can you make a switch again and you can forget about spontaneous travels to the more remote areas of Denmark" (Graubæk, 22 September 2012).
- Traffic produced would not be currently of the same scale as when it comes to this generated by a new gasoline station. Although, question of future traffic generation by BSSs holds true for the future.

Chapter 7 Process of Battery Swap Stations establishment in Denmark

The goal of this chapter is to describe the BSS establishment process. European municipalities, expected key receiver of this report, are generally involved in issuing permissions. As was learned on the basis of Danish experiences with setting up BSSs, the process followed the following structure:

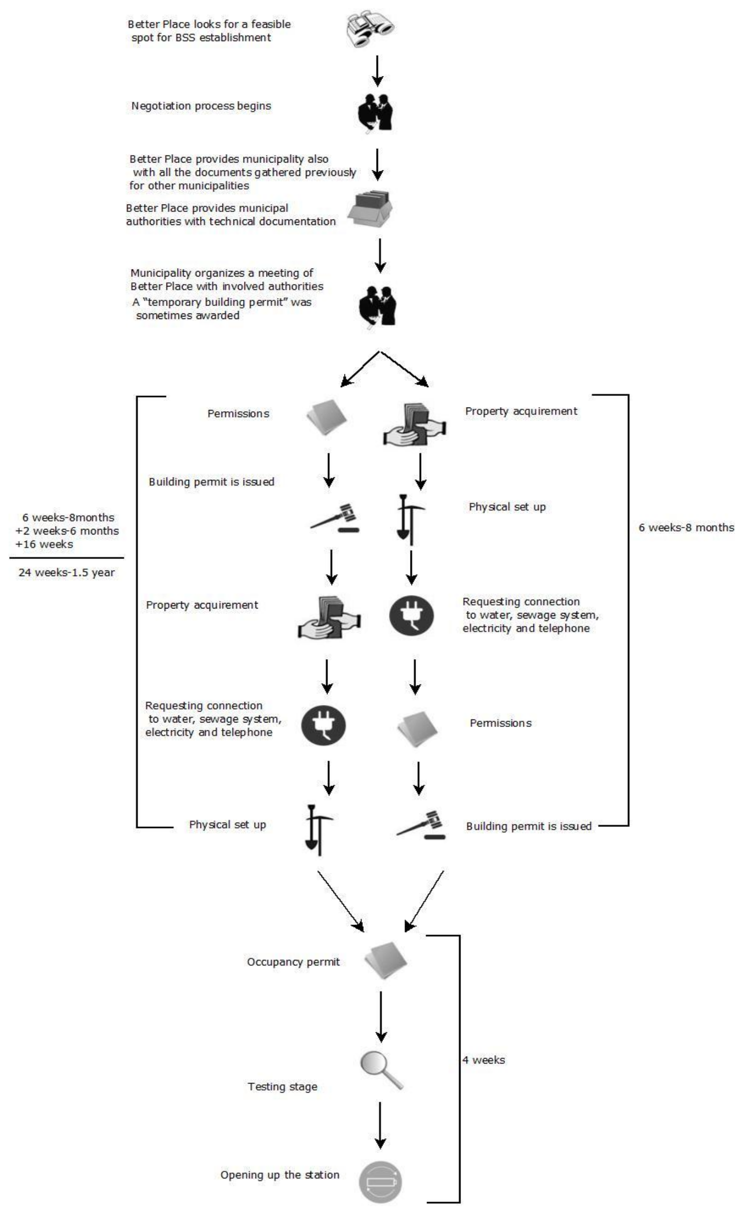


Figure 41 BSS setup process in Denmark, own drawing

Better Place looks for a feasible spot for BSS establishment. Better Place enters into contact with a municipality, where they want to establish BSS and inform about the preferred location criteria. Municipality proposes Better Place several spots located on public property. Better Place checks if these locations are feasible for them. In the meantime, Better Place also looks for potential sites.

Negotiation process begins: Better Place and municipality tries to match location criteria of both sides. Better Place either chooses one of the locations proposed by the municipality, or a spot belonging to a private property owner from which they will buy or rent the land.

Better Place provides municipal authorities with technical documentation of the BSS to be constructed. Required documents are as follows:

a) Technical detailed BSS's building drawing including specific drawings concerning: sewage system, fire protection system, the tightness of the building where it is in contact with the soil, sound insulation against neighboring properties and access level to BSS.

b) Documentation supplementing technical drawings (detailed description is included in chapter 3)

- Stability, load-bearing structure of the building and energy performance calculations
- fire safety, sewers/drainage, ventilation, heat loss, documentation showing that structures and materials are free of any moisture content which would risk the development of mould in the building once occupied (engineer's report),

c) Technical property plan including: BSS building size, number of parking places, roads area and the transformer station.

In order to speed up the process, **Better Place also provides the municipality with all the documents gathered previously for other municipalities,** where they already gained the building permit for a BSS.

Municipal authorities assist Better Place in the permissions obtaining process. However, when it comes to BSSs **municipality organizes a meeting of Better Place with involved authorities**: fire brigade, police, urban planners and local citizens' representatives. All the measures, requirements are discussed during this gathering; also what municipality will not agree for is discussed. Thanks to information gathered, Better Place looses less time on permissions' obtaining process, since the requirements are well known.

Municipalities also try to give a preliminary answer if there are no obstacles regarding for instance environmental requirements, safety or traffic issues. Therefore time needed to find the feasible spot decreases significantly. Last but not least, a **"temporary building permit" was sometimes awarded**, if the preliminary decision on the compliance with local plan/rural zone permit was made.

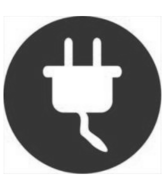
However, the final municipal decision could also be a rejection; this was a risk which Better Place could take if timing has an importantance for them.

There are several **permissions** needed to be obtained, mostly the same as for all constructions in Denmark. The whole process is covered with one procedure, applying for a building permit, but involves the action of many authorities managed by the municipality. On the basis of the BSS's technical drawing provided following issues are being checked:

- Fire safety, regarding the building structure and emergency plan in case of batteries being accidently broken,
- Waste water management plan (waste water produced from car wash facility),
- Rain water drainage,
- Accidently broken batteries – Better Place has to obey regulations regarding the way concrete is to be made, in order to avoid soil contamination,
- Noise generated – no special requirements regarding BSS, the same as for other types of buildings,
- The structural engineer certificate,
- Building compliance with the Real Estate Registry's regulations and requirements,
- Compliance with a local plan or obtaining a rural zone permit, depending on the land use of the property where the BSS is to be located. Within local plan/rural zone permit specific location of BSS is approved. The most important issues regarding BSS location are: environmental class – minimum distance from residential areas, which takes into account safety, environment pollution and traffic generation reasons.

Building permit is issued after all the specific permissions are obtained, which allows construction start.

Property acquirement. Better Place prefers to rent a property instead of buying. It is because rural areas in Denmark are divided into big size properties which can be mostly sold only as a unity (cannot be divided). This land structure affects BSSs' as they are to be mainly located next to highways and between cities – within the rural zone area. Negotiation for a specific spot starts early, before the permissions are gathered. However, property is not acquired before all the permissions are gathered, so it is sure that BSS can be built at the specific spot. It takes from 2 weeks up to 6 months.

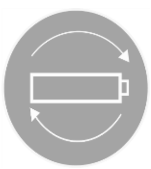


Requesting connection to water, sewage system, electricity and telephone are additional procedures which Better Place must undertake without municipal assistance. It is a task of Better Place to find a sewage company, energy and telephone facilities provider, as well as to discuss the costs of it, and which permissions are needed. It is because Danish municipalities are not allowed to point out a private energy supplier. Plugging in to the smart grid is not regulated by additional permissions required from Better Place; electricity supplier plugs in BSS to smart grid and therefore it is his responsibility to comply with the requirements concerning smart grid utilization. BSS's operator role is to adjust charging technology used for smart grid connection.

Physical set up of the BSS stage. During the construction process an unannounced inspection regarding either fire or sewerage law can take place. The physical set up takes 16 weeks.

Occupancy permit is obtained and the building can be used after **compliance with all the requirements** of the physically established building was examined, especially focusing on fire protection issues.

Testing stage includes machines' integration stage, Station's integration stage, testing charging process stage. It takes all together 4 weeks.



Opening up the station: battery swap can take place, EVs can communicate with the BSS so the battery is charged JIT and in case of emergency contact with the service centre is ensured.

Chapter 8 Battery Swap Station concept transferability to other types of vehicles

When developing solutions for private electric vehicles, a combined focus on both electric cars and electric trucks is an obvious opportunity, which could be utilised. This is also valid for battery swap stations, which after some modifications potentially can be used for vans and smaller trucks as well. This section looks into how Transport and Logistics Centres, city distribution and Battery Swap Stations can play together to live up to EU's goals on the transport area.

The text in this chapter is based on the assumption that other types of models than the Renault Fluence Z.E will be ready for battery swaps. From Renaults own selection this could be vans or trucks like the Renault Kangoo Z.E. the Kangoo Maxi Z.E.

Concerning larger vehicles the Renault Midlum Electric is another option, though this will require some additional updates of the physical dimensions of the battery swap stations as the vehicle dimensions of the Midlum are too big to fit into the current stations.

8.1EU legislation on the field

According to EU's "White Paper for Transport - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" one vision for a competitive and sustainable transport system is to achieve "*a 60% GHG emission reduction in 2050 compared to 1990 levels."* This means that the following goals should be achieved for the transport sector

- *"Halve the use of 'conventionally-fuelled' cars in urban transport by 2030*
- *Phase them out in cities by 2050;*
- *Achieve essentially CO2-free city logistics in major urban centres by 2030."*

(COM (2011) 144 Final, 2011)

These are ambitious goals which require actions for both private transport and goods transportation in order to be fulfilled. Using the Battery Swap technology is one way to take a step towards their fulfilment, but a number of factors need to be in place to enable a smooth implementation.

8.2 Current vehicles and their designs

The Renault Kangoo Z.E and the Renault Kangoo Maxi Z.E are at the moment not constructed to enable battery swap, so they can in their current versions only charge via normal charging stations. The wheel gauge on the Fluence is 1537 mm on the front and 1555 mm on the rear, the numbers for the Kangoo are 1521 mm on front and 1531 mm on the rear. With this small difference in between the wheel gauge of the two models, the battery swap stations are ready also to accommodate the Kangoo Z.E and Kangoo Maxi Z.E. Concerning the height the Fluence is 1458 mm and the Kangoo 1844 mm. This height will easily enable the Kangoo to enter the battery swap stations.

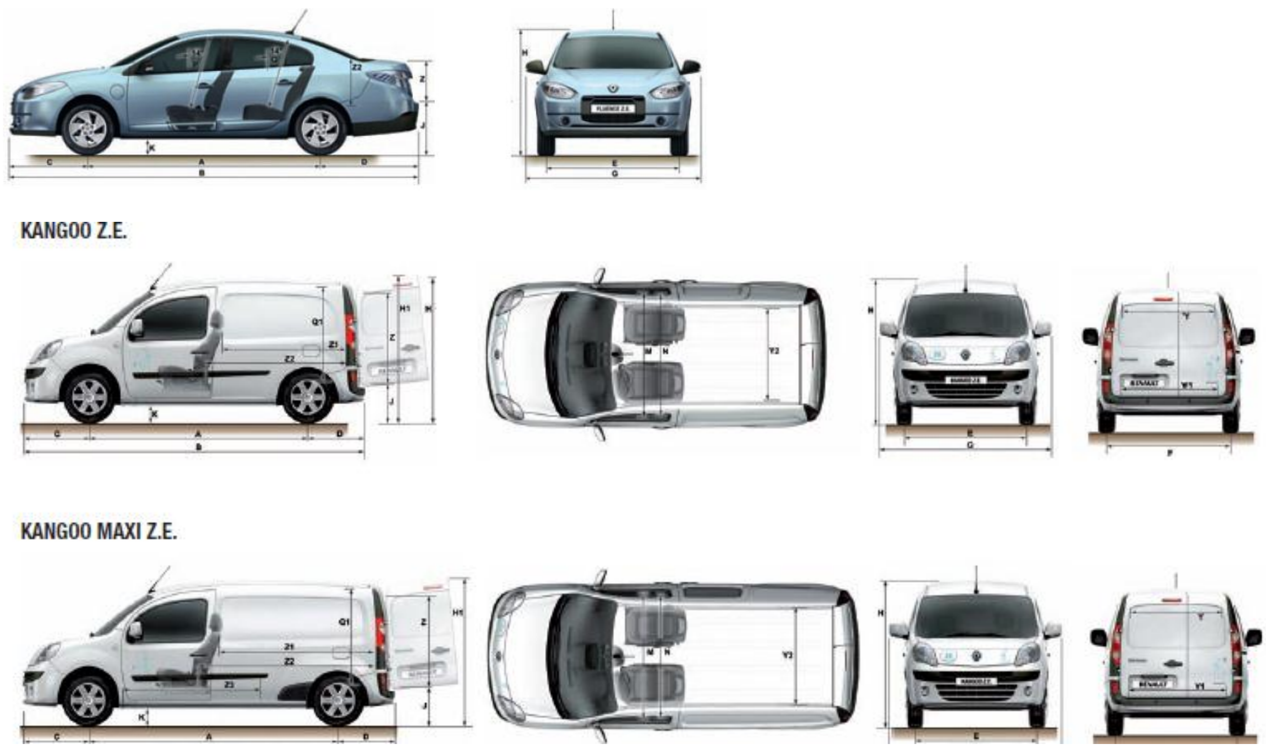


Figure 42: Renault Fluence Z.E, Renault Kangoo Z.E and Renault Kangoo Maxi Z.E, (Renault, 2012B)

The bigger vehicle Renault Midlum (Figure) is also not ready for battery swaps. But, as shown on Figure the station design and land purchase is planned, so an additional lane for vehicles can be added, and this lane could potentially have a higher entrance, which would allow for larger vehicles.

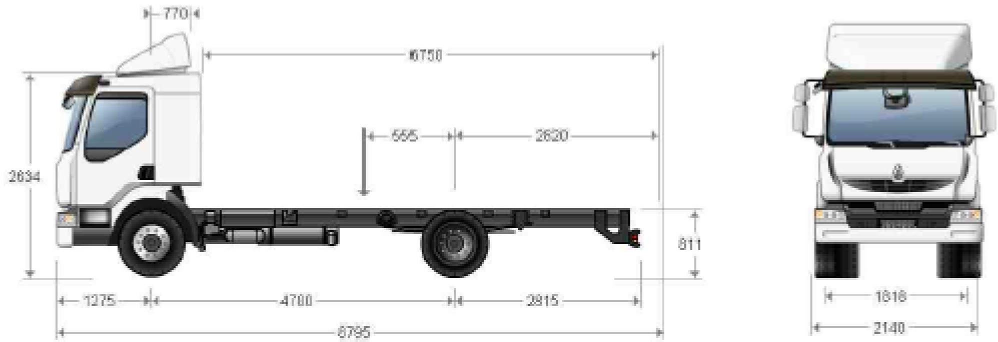


Figure 43: Renault Midlum dimensions, (Renault, 2012C)

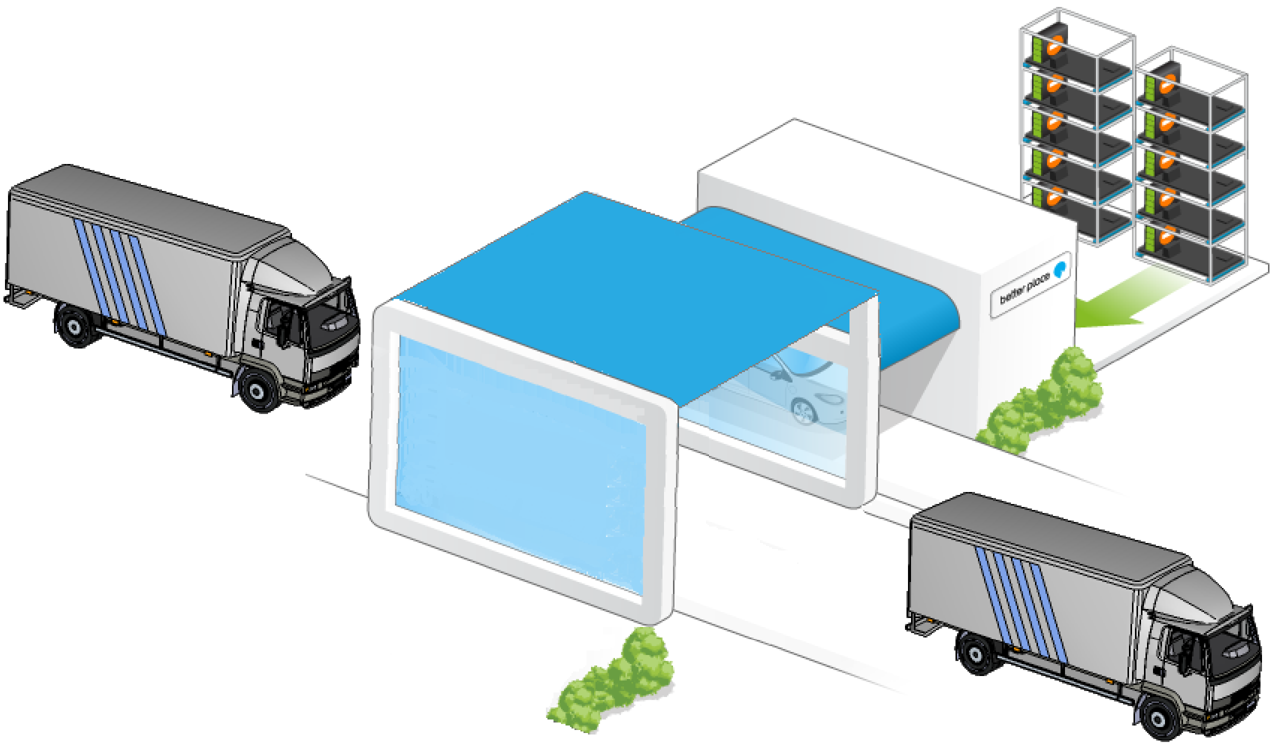


Figure 44: Battery Swap Station expanded to encompass two lanes, one for private vehicles and one for smaller trucks (own drawing based on Better Place)

8.3 City distribution concept

Using electric trucks and vans for distribution is an option which has been examined in the E-Mobility NSR activity 7.3 report on *"Comparative Analysis of European Examples of Schemes for Freight EV's*". Combining the knowledge from above mentioned report with the knowledge optioned in this contemporary report, it can be concluded that the stations could also be technically feasible for changing batteries of smaller trucks and vans. This is mainly due to the fact that the battery swap stations can handle batteries in different sizes and shapes. The only two things which needs to be adapted are the dimensions of the second lane and the toolbox on top of the batteries, the latter is according to Better Place (Salomon, 2012) possible, as long as the battery is taken from underneath the vehicle. Moreover the new toolbox and the dimensions, there are no significant machinery retrofit required to switch larger truck battery at current battery swap stations. Therefore, if the electric trucks with switchable batteries appear on the market they can quickly start using battery swap stations.

From a commercial point of view there should also be an incitement for companies to invest in Electric trucks for city distribution purposes on top of the environment benefits. One way of promoting environmentally friendly transport solutions is putting restrictions on the use of conventional vehicles with ICE's. In many larger cities Low Emission Zones have been implemented to reduce pollution and improve the air quality in city centres**. Low Emission Zones** are restricted areas where it is required that diesel trucks and buses over 3 ½ tons are equipped with particle filters that live up to the EURO 4 norms or higher. Approved particle filters intercepts approx. 80% of the particles from a diesel engine. In relation to electric vehicles, it means that it is beneficiary for companies to acquire electric vehicles to their fleet of vehicles as the electric vehicles automatically meet the requirements for driving in the zones" (E-Mobility NSR, 2012A)

The report on *"Comparative Analysis of European Examples of Schemes for Freight EV's*" showed that the utilisation of electric vans and trucks for city distribution purposes has a number of benefits, including:

- Electric Vehicles have no CO_2 and noise emission
- Electric Vehicles are loaded at transport centres/ terminals outside the city centres where city distribution goods are consolidated.
- Electric Vehicles can enter city centres also during night hours as they produce less noise.
- Electric Vehicles can pass environmental (low emission) zones.
- Electric Vehicles drive on short fixed routes and therefore seldom have longer detours. Range is not a critical issue to cope with for distribution purposes.
- At present the largest electric trucks produced by OEM's have a payload up to 10-12 tonnes, however the one of 22 tonnes payload is tested in a pilot project.
- With a range of minimum 100-120 km, distribution in most European cities can be performed on one charging before returning to the Transport Centre. Therefore, a low number of charging spots spread within the city is required. Charging spots can be located mainly at the companies' premises.

With these benefits in mind, it is evident that electric vehicles and city distribution can be both a commercial and environmental interesting solution, but a requirement is that the goods are collected and bundled. This is here the Transport and Logistics Centres comes in.

8.4 Transport and Logistics Centres

To fully utilise the potentials of electric vehicles for city distribution purposes it is important that they transport high volumes of consolidated goods. For enabling this, an important aspect is the bundling of goods at Transport and Logistics Centres. A Transport and Logistics Centre is defined as:

- A Logistic centre is a centre in a defined area within which all activities relating to transport, logistics and the distribution of goods - both for national transport and international transit, are carried out by various operators on a commercial basis. The operators can either be owners or tenants of buildings and facilities (warehouses, distribution centres, storage areas, offices, truck services, etc.), which have been built here.

- In order to comply with free competition rules, a Logistics Centre must be open to allow access to all companies involved in the activities set out above. A Logistics Centre must also be equipped with all the public facilities to carry out the mentioned operations. If possible, it should include public services for the staff and equipment for the users.

- In order to encourage intermodal transport for the handling of goods, a Logistics Centre should preferably be served by a multiplicity of transport modes (road, rail, sea, inland waterway, air). To ensure synergy and commercial cooperation, it is important that a Logistics Centre is managed in a single and neutral legal body (preferably by a Public-Private-Partnership). Finally, a Logistics Centre must comply with European standards and quality performance to provide the framework for commercial and sustainable transport solutions (Bentnzen, 2003).

Two of Better Place battery swap stations have been located at strategic, important and practical locations where they in the future potentially can be used for freight transportation as well. These are in STC – Scandinavian Transport Centre in Koege and at gateway E45, formerly known as Danish Transport Centre, in Vejle. Both centres have battery swap stations strategically located, thus fitting the needs of private users, but potentially also the needs of goods vehicles like vans and smaller trucks.

8.5 Concept of using Battery Swap Stations for trucks

Trucks are much larger than private cars, thus their batteries needs to have bigger capacity. The time of charging their larger batteries at normal charging points would therefore be much longer. A rough comparison of the batteries' size will show that charging time for vans and trucks roughly can be estimated to be 5-6 times longer than of personal EVs (comparing 120 kWh battery of a truck with 22 kWh battery of personal EV (Smith Electric, 2011). Therefore charging truck batteries is a much bigger challenge than personal cars, despite of the fact that fast charging technology is developing quickly. This is here the battery swap technology comes into the picture. With an adaption of the system and the production of a truck with switchable battery the re-charge will no longer take 5-6 times longer, but can be handled in 4-5 minutes like for private cars. This will enable the electric trucks to be in operation at a 24/7 scale, whereby no time is lost for recharging. Since the trucks uses very fixed routes for their distribution and can drive up to 250 km on one charge, the battery swap station only needs to be located at the transport centres from where the distribution starts and ends and goods are consolidated.

8.6 Future steps

Better Place aims at serving other than Renault Fluence Z.E (currently the only vehicle which can utilise BSSs) brands and models, with different shape and size of the battery. The main retrofit needed is a toolbox (particularly set of screw drivers) which performs the switch. However, these new toolboxes must be designed by the respective car manufacturers. Better Place considers BSS's adjustment for serving larger vehicles, but still an OEM needs to be involved.

Chapter 9 Recommendations and conclusions

9.1 Recommendation regarding changes in the law

Recommendations listed in the following chapter aim at showing how the public authorities in different European countries can support e-mobility spread, specifically, how they can support the charging infrastructure establishment process in order to make the process quicker, cheaper and to ensure that it is feasible for users and city administration: well accessible, safe and aesthetic.

a) Changes in the law directly influencing charging infrastructure

- **Regulations enabling financial support for charging infrastructure should be in place**. Public support for charging infrastructure is important since people will not be able to utilize purchased EVs if charging infrastructure is not provided. Municipalities can undertake charging infrastructure support either through **subsidies for charging points establishment** (still keeping in mind proper distribution throughout the city and accessibility needs), through **payment exception** for a charging infrastructure, or through **securing free electricity for charging at CPs**. The last one is an idea of some Danish municipal authorities, so that charging infrastructure owners do not pay the electricity bill for the energy consumed from CP by located on public properties (therefore excluding shopping centres, gasoline stations etc.). In the Danish context it would concern Better Place, but not CLEVER, as the latter's customers do not pay for using CPs and QCPs (except of the electricity charged from home charging stations). Hence, it would be impossible to implement this law in Denmark, as the Danish law does not allow giving advantage to one competitor over another.
- **Regulations taking into account aesthetics of CPs, QCPs and BSSs should be made** (especially if charging infrastructure is located within the densely inhabited areas). General guidelines should be provided by the national level authorities, while more specific guidelines should be created by each municipality, adjusting them to each specific urban structure.
- **Regulations taking into account an increased traffic around the BSSs, CPs and QCPs should be made** by municipalities, as they are located within the cities borders; but in the future it can be also an issue of BSSs, if located within cities, as planned by Better Place
- **Regulations regarding dealing with used batteries recycling/ utilization are needed**. The building permit does not include any issue on dealing with used batteries. There is regulation protecting from soil contamination from accidently broken batteries, but no permission concerning used batteries' utilization are required yet. However, as was learned during interviews, the reason for this is not lack of necessity for such a regulation, but rather early stage of BSS implementation; in this moment location criteria and building permit where these of municipal interest.
- **Differentiation between municipal location criteria for charging points and fast charging points should be provided** (differentiation not noted by Danish municipalities, but could be of importance). As was learned during one of the interviews, municipalities conceive charging points as not generating additional

traffic when located next to shopping malls, as only customers will charge. However, the situation differs when it comes to fast charging points, even though it has not yet been noted by the municipalities. Firstly, traffic generation is higher, as FCP has bigger throughput than CP, when comparing charging time. Secondly, safety issues are more significant concerning FCP, since the power flow is much bigger. However, thanks to the shorter charging time FCP does not require as many parking places reserved for charging as CP.

b) Changes in the law indirectly influencing charging infrastructure

- **Standardization of plugs for EVs' charging** should be supported by the national authorities. If the plugs were standardized in Denmark, then it would be possible to enforce all charging infrastructure operators to enable use of CPs and QCPs by all EV drivers, also of their competitors. The reason is that there is already present legislation within Danish law, which stipulates that charging infrastructure set up on public property should be available for all EV users However, lack of plug standardization already creates problems for EV users: there are huge areas within Danish cities where only Better Place's or only CLEVER's infrastructure is present.
- **All forms of EVs purchase and use facilitation** will support charging infrastructure spread:
  - free parking places for EVs,
  - EVS exempted from taxation for a longer period of time than 5 years (as it is currently planned in Denmark) so that drivers can rely on legislation which support them, they can buy an EV, which is expensive and do not have to be worried about additional costs to come.
- **Differentiation in law between incentives for so called "black" and "green" EVs**. This would ensure that EVs will play the role assigned to them – replacement of polluting means of transportation. Hence, they should be fuelled with electricity produced on a sustainable basis, from renewable resources.
- **Removal of legal barriers for the use of renewable energy sources** should be secured by the national authorities. This will ensure that the majority of EVs on roads are "green" ones. This can be done by adjusting timing of EVs' and charging infrastructure support with transition to fossil free energy supply. This aim seemed to be secured by the Danish National Objective: become 100% fossil fuel independent till 2050. Already in 2020, Denmark is to reduce its greenhouse gas emissions by 40 % compared to the 1990 level, and 50% of the electricity production ought to come from wind energy. However, as was found during interviews conducted, the legal side is still slowing down the process of transformation to renewable resources based energy production. An example can be a limit of maximum 6kWh solar panels per household.
- **Legal regulations concerning smart grid solution should be in place as it supports BSS's profitability**, this issue should be rethought by public authorities in order to enable smart grid inclusion into BSSs system.
- **New subsidies for EVs should be provided if municipalities are these to promote e-mobility**, giving an example while using EVs. The reason is that it is more expensive for municipality to acquire an EV than a ICE vehicle, as municipalities are already exempted from VAT while purchasing cars (diesel, gasoline fuelled).
- **Permitting charging infrastructure's location in the high accessibility areas**.
- **Permitting charging infrastructure's location in well visible and broadly visited places**.

9.2 Recommendations regarding location of BSSs, CPs and QCPs

a) Recommendations in regards to the current circumstances

- BSS seem to be a indispensable tool to achieve e-mobility spread as it gives EV's driver a quick charging opportunity, which is especially important during long trips. BSSs are currently the only charging equipment located outside the cities, and therefore the only enabling travels between cities. Therefore, **people commuting for longer distances should consider buying EV with a switchable battery** instead of EV with a mounted one. In the future, it can occur that EVs with mounted battery will be more feasible for long routes, but only if fast charging technology development ensures similar charging time as battery swapping does.
- **Either QCP or BSS seem to be indispensable within the urban areas**, since as much as 25% of EVs' drivers will not be able to charge their cars with a use of home charging station (*Explanation of frameworks for charging points,* Danish Energy Agency). The reason can be type of residential area inhabited – consisting of blocks of apartments, thus in most cases lacking charging facilities. In this case BSSs seem to be more feasible than currently available QCPs, as the time needed is 4 times shorter concerning BSSs. Even bigger number of EV drivers in need of using charging infrastructure out of home would appear (placed on the public property, next to supermarkets or at work places) if also number of EV drivers commuting distance equal to EV's minimum range is taken into account[6]. People commuting daily more than 80 km accounts for 11% of commuters (all means of transport included). If also shopping on the way home is included in the total distance then also these commuting above 60 km should be included. Then the number of commuters in need for charging outside home can rise even up to 16.5%.
- **Local planning should ensure proportional dispersion and accessibility of charging infrastructure.** Hence, municipalities should control the spread of charging infrastructure within cities in order to prevent appearance of a mix of "blank spots", where charging infrastructure is absent, and high concentration of them in the other city's parts (Energi Styrelsen, 2011).
- **Concerning cities, QCPs and CPs appear as a more feasible charging solution than BSSs**: they require less space (about 1m^2 for CP+ reserved parking places), are much cheaper and are allowed to be placed within residential areas, while BSSs are not allowed to be located closer than 50 m from them. However in the future their location can be desired within city depots.
- Location restrictions for BSSs, QCPs and CPs should be also differentiated regarding traffic level generated.
- Within cities, e-mobility shift is inherently connected with additional space needs and therefore with the land use patterns' changes. It must be kept in mind that **CPs generate parking problems** if new parking places are not provided. The reason is that these parking places should be reserved only for charging and therefore not used for a majority of time. This problem is especially important nowadays, since a very small number of ICE cars are replaced with EVs. Therefore, they create an additional cost which could easily end up being covered by the municipalities. However, when in the future less ICE are in use, gasoline stations can be continuously demolished and replaced by BSSs, QCPs or CPS.

[6] 80 km is a minimum range of Renault Fluence in "extreme weather conditions", average range is 100 km.

- Location of BSSs: when Better Place applies for a location to build a BSS, then the **municipality should take into account, that they will look for a larger area than the dimensions of a BSS**, because they also need to put a transformer station next to BSS and also they are always securing the land for a built of second lane, either the same size, for personal cars or bigger for trucks. There should be minimum 800m^2 secured.
- Location of BSS: **Municipalities while considering location of BSSs should bear in mind that their placement close to electricity transmission/distribution network is desired**, since the amount of additional infrastructure needed to plug in BSS to grid is decreased then. However, location next to transformer station is not considered necessary by Better Place, as each BSS site contains its own transformer station.
- Location of BSS: **Municipalities should, while considering location of BSSs, be aware that the most important criterion for BSS location is good accessibility**; it is weighted alone as 50% when the decision on the BSS location is made.
- Location of BSS: **Better Place prefers to locat BSSs next to rest areas**
- Location of CPs: A preliminary recommendation could be that **CPs should be distributed within the city limits the way that they are within walking distance from multi-storage residential areas**. This will ensure that EVs can be charged during nights and therefore used every day. Likewise, CPs establishment next to the single family houses districts should not be prioritized, as they have a possibility to use home charging stations.
- Location of CPs: **Local increase of local energy consumption should be taken into account** while locating charging infrastructure, especially when it comes to QCPs, as their energy use per time unit is the highest one.

b) Recommendations in regards to the potential future circumstances (when share of EVs' in the car market become more significant)

- **BSSs would probably long stay the most feasible charging solution for regional electric transport** (commuting for long distances), as the charging time at currently available QCPs is 4 times longer.
- **BSSs could become also an important part of charging system in cities**, if charging time at QCPs does not decrease soon. It is because of the parking needs induced by CPs and QCPs.
- **QCPs would stay the most feasible solution for charging within urban** areas if charging time would decrease, since they require less space (about 1m^2 of CP + reserved parking places) and are allowed to be placed within residential areas, while BSSs are not allowed to be located closer than 50 m from them. However, even if charging would take 5 minutes, still there must be reserved places for cars waiting to be charged (the same situation in regard to BSSs).
- The condition is that city administration can ensure a sufficient number of parking places for charging reasons as well as for ICE already present in the city. It is possible that in many cases the only way to guarantee this would be to build new parking lots, possibly on the municipal cost. Therefore it is recommended that **public authorities keep this future situation in mind and monitor the speed of EVs expansion.**

10. Conclusions

- **Technical issues conclusion**:
  - BSS is the only charging solution available enabling long distance travels with electric vehicles.
  - The BSS concept is prepared for serving EV users, it enables ongoing communication with EVs and is prepared for smart grid use.
  - Smart grid is inevitable to attain BSS's profitability.
  - BSSs are not creating a big pressure on energy supply system. Much larger pressure is put especially by QCPs but also by CPs. Therefore these two last elements of charging infrastructure for electric vehicles should be plugged into smart grid in the near future.
- **Financial issues conclusion**:
  - BSS is an expensive solution: 10 times more expensive than QCP and 750 more expensive than a gasoline spot. However it is the only solution enabling long distance travels and can occur to be a more feasible solution in specific urban areas (parts of cities with primarily high-rising buildings).
  - Smart grid solution is technically developed to serve home charging stations for EVs. However, according to Dong Energy, smart grid is not to be quickly spread among individual consumers. It is because the potential profit from smart grid use is too small compared to effort needed to use smart grid: charging EV when it is profitable.
- **Legal issues conclusion**:
  - The legal process of BSS's set up is relatively easy and short as no significant problems are connected with this solution.
  - There were found some important gaps in the Danish law which overcoming can contribute towards smooth e-mobility spread, such as differentiation in law between incentives for so called "black" and "green" EVs and removal of legal barriers for the use of renewable energy sources.
  - Financial support for charging infrastructure is not available now and it is caused by the fact that there is not present a law enabling it. There must be found a legal reason for such a support so that municipalities can provide it. It is because municipalities are not allowed to enrich a person or a company, thus they cannot support for instance just Better Place, but they have to support all the competitors present in a country.
- Incentives for EV users (direct and indirect ones) are necessary to ensure spread of e-mobility, since EVs in many ways still are less feasible than ICE vehicles.

- BSS enables travels for long distances and is the only available refuelling battery solution for such travels.
- It is quite obvious that charging infrastructure for EVs will not become profitable till the moment when a significant number of EVs appear on the roads. Therefore financial and legal support of EVs is as much important as BSSs and CPs support; and also the other way around: EVs support alone will not bring e-mobility into roads if charging infrastructure is not developed enough.
- Energy objectives made by Denmark give the most important argument for public authorities why e-mobility support is needed. Transition to energy production from renewable energy sources would be significantly supported by smart grid implementation, as this solution provides a more efficient and flexible energy management. However, this solution is to be broadly spread only if an extensive energy storage is provided. Currently, only big number of electric cars is a sufficient storage for energy supply system based on renewables.
- BSSs are not alone an important element of smart grid, they are not playing a leading role in the smart grid solution implementation, as the energy use by BSS is not that significant. However, smart grid is important for BSS profitability, as Better Place will be paid for energy supplies back to grid, when requested.
- Competition between charging infrastructure providers induces their lower accessibility for EV drivers. There are areas within Danish cities where only Better Place's or only CLEVER's infrastructure is present. Hence, accessibility of these areas with an EV is significantly decreased.
- Denmark, with its topography and short distances is a country feasible for electric cars implementation.
- Green municipality's image was found during interviews as an important tool to attract inhabitants, investors and even tourists: EV users from Norway are more willing to visit Denmark, because charging infrastructure is in place here.

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