

TOP-NEST

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Electric mobility case study for Denmark

Case study: Better Place – an effort of creating new actor roles and infrastructure for electric car mobility

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Introduction

After a period of 15-20 years of little activity, the area of electric cars has in Denmark as well as in a number of other countries received renewed attention over the latest 6-7 years. The company Better Place has been a prominent and visible actor in Denmark in this field in the period from 2008 to 2013. In the early summer 2013, the company went bankrupt, leaving customers, investors, and collaboration partners in an uncertain and in many cases bad situation. As analysts of socio-technical change, we know that change processes are often uncertain and can go up and down to a considerable degree. Moreover, we have an important method principle of symmetry, saying that we can only understand dynamics of socio-technical change fully if we do not pay attention to proven winners only, but include both failures and successes in our studies (Bijker 1995). We can learn both from troublesome periods and successful periods. This is why it is relevant to present a case study of Better Place as this paper does. We will not take the bankruptcy of Better Place as a definitive prove of that Better Place was wrong in their contribution to the development of the electric car area, but remember that for a long period, Better Place was considered a winner by many, and not a loser. Moreover, parts of the Better Place equipment, solutions, and experiences will be used also in the future, despite the bankruptcy. The international energy company E.ON has taken over parts of the charging infrastructure and is continuing its operation (E.ON 2013).

Better Place was an international company founded in 2007 with headquarters in California and market activities primarily in Israel, Denmark, and Hawaii. In addition it had more limited activities, like demonstration projects and strategic alliance making, in e.g. China, Japan, Australia, the USA, and the Netherlands. The present case study focuses mostly on the activities in Denmark and the daughter company Better Place Danmark A/S, without leaving the international aspects out of consideration. For simplicity reasons, the term 'Better Place' is used in the following as short name for Better Place Danmark A/S, or for Better Place in general (Denmark and other countries) in places where there is not risk of misunderstandings. When it is specifically the activities outside Denmark that are referred to, the term 'Better Place int.' is used.

The case study employs a value-chain focused approach that is defined in the Top-Nest project. The first chapters describe the value chain characteristics of Better Place and the actors, technologies and elements developed in the value chain. Thereafter appear chapters on market characteristics, geographical scope, institutional context, and path dependencies in the case.

1 Value chain characteristics

Better Place was a developer and provider of charging infrastructure and electric car solutions for households and business users of cars. More specifically, Better Place provided products in the shape of *subscription-based electricity and charging service for car users, charging points and battery shift stations*.

The activities and role of Better Place are difficult to account for fully through a traditional (one-dimensional) value-chain perspective. There are two reasons for this. Firstly, the economy of Better Place was based primarily on investments and venture funding from public and private investors, and not as traditionally for industrial companies, from sales of their products. Though ordinary commercial sale took place in 2012 and start of 2013, Better Place did not reach a fully commercially based economy. Secondly, and maybe more important, Better Place aimed with its solutions to deliver a systemic package that not only covered more than one element in an existing value chain, but cut across it and suggested a new system order and role distribution in the field. Different terms have been suggested for an actor with a role and business model like Better Place, e.g., 'electric car operator' (Energinet.dk 2010) or 'fleet operator' (DEA 2010). Better Place itself most often abstained from such relatively function-specific terms for themselves in favor of a broader and more general notion of being the world's *leading provider of electric car services and infrastructure*.

Membership subscription to Better Place included (Jul 2012):

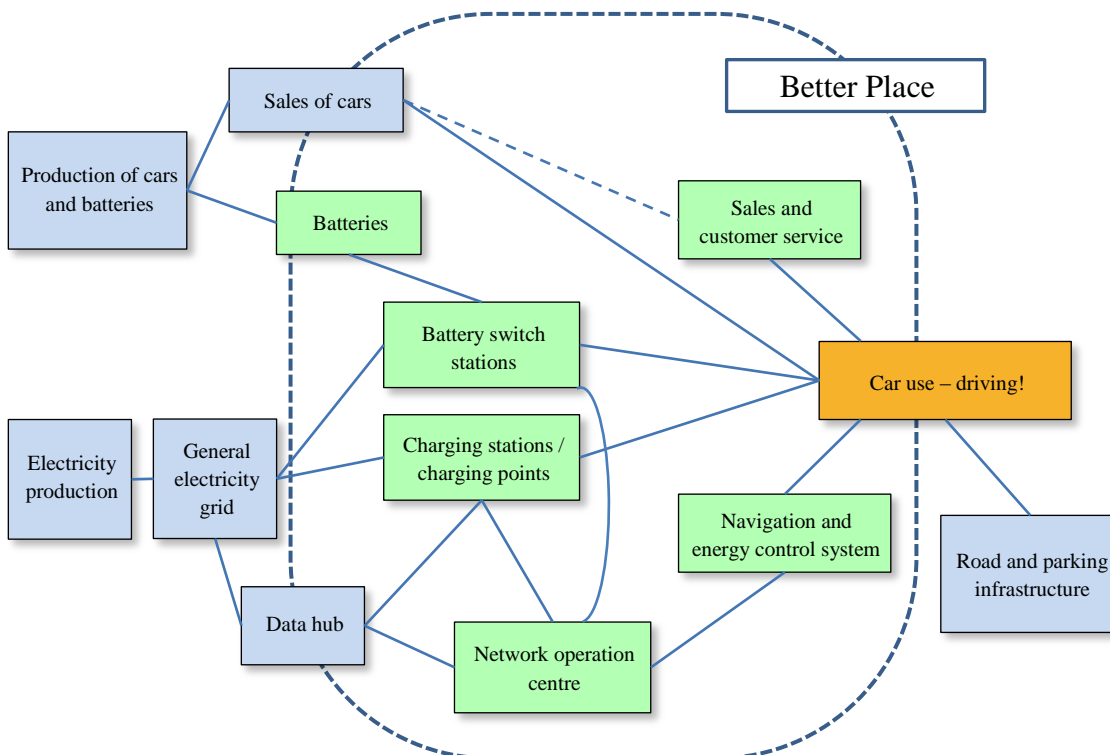
- Own charging point – operated and maintained by Better Place
- Leasing of battery
- Free use of public charging points
- Free use of battery switch stations
- Unlimited electricity (within certain annual kilometer limits)
- Navigation system including energy control, route planner, and maps over battery switch stations and charging points
- Online self-serve and 24/7 customer service (by phone)

Memberships for business customers can include leasing of an electric car as well. The price for subscription was between approximately 1.500 DKK/month and 3.000 DKK/month (200-400 euro/month) depending on annual kilometer limit: max 10000 kilometers/year in the former case; and free mileage in the latter case (Better Place 2013).

1.1 Main activity segments of the value chain

A simplified picture of the main activity segments of the value chain in the case of Better Place is shown in Figure 1. In the following, the main elements and actors in the value chain of Better Place are described. As appears from the figure, Better Place relates to the general value chains of electricity, of cars and of road transport systems.

Figure 1: Main activity segments of the value chain of Better Place.



1.1.1 Cars

Better Place collaborated with a number of suppliers of cars amongst others Renault, Nissan and Citroën and Tesla Motors. Among the cars showcased by Better Place in 2013 are Renault Fluence Z.E., Nissan Leaf, Renault Zoe, and Citroën C Zero, ranging from a relatively large family car over 'fast hatchbacks' to a smaller 'commuter car', still with four seats though. To this come the luxury sports car Tesla Model S and the small delivery van Renault Kangoo Z.E. The collaboration with the car suppliers concerned sales and guidance of customers in choice of electric car and integration of the Better Place navigation and energy control system. In some cases, not least Renault and Nissan, the collaboration went deeper than this and was connected to the technical design of the car and its battery and charging technology.

1.1.2 Batteries

The batteries for all the cars mentioned above are of the lithium-ion type in sizes around 22-24 kW; smaller for Citroën C Zero (15 kW) and considerably larger for Tesla Model S (60-85 kW). The batteries were owned by Better Place; not by the owners of the electric cars. The batteries were supplied in collaboration with the car manufacturers.

The car model Renault Fluence Z.E. has played a special role for Better Place. It was introduced on the market in 2012. While other current car models have batteries that are fixed in the cars, Renault Fluence Z.E. is constructed with switchable batteries that can quickly be changed at battery switch stations. Instead of waiting for recharging, the flat battery can be replaced by another fully charged battery. The switchable batteries are one of the points on which the Better Place case is radically different to the other current solutions. The difference both concerns the business model of Better Place and the delimitation of what are considered as integrated parts of the car and what are considered as loose components and equipment attached to the car. Hence, it is challenging the accepted understanding of what a car is.

1.1.3 Infrastructure

1.1.3.1 Battery switch stations

As the first place in Europe, 17 battery switch stations were established in Denmark in 2011-2012. They constitute one of the components in the Better Place infrastructure. At the battery switch stations the car users can get a fresh battery in less than 5 minutes (Better Place 2011). The battery switch is done fully automatically by a robotic shuttle that removes the depleted battery from the underside of the car. The battery switch stations are meant to be used for longer trips primarily. They are located close to the motorways connecting the different parts of the country, see Figure 3.

Figure 2: Battery switch station (photo: Better Place).



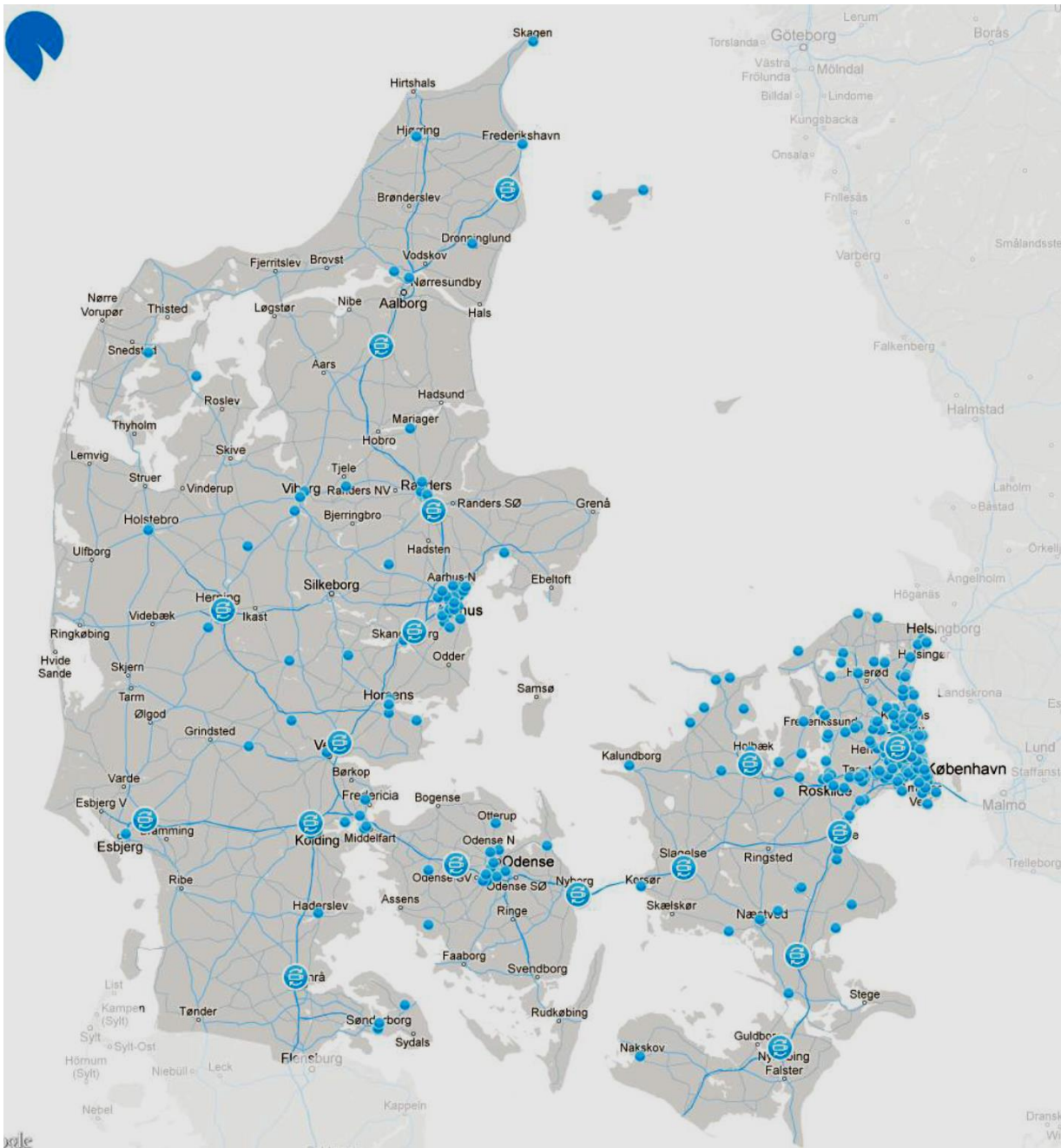
The battery switch stations are developed in interaction with a.o. Renault, Nissan (the Renault-Nissan Alliance), the battery provider A123 Systems and the Danish consultancy company Alectia. Though Renault Fluence Z.E. is the only car currently on the market with switchable batteries, the battery switch robot can in principle switch batteries of multiple types and sizes as long as the batteries are mounted from the underside of the car (Better Place int 2010a, Alectia 2011).

The buildings of the battery switch stations are modular constructed and a complete station can be established in around 2 months. In addition to the 17 established battery switch stations, two other were planned in Denmark, but the construction was stopped in 2013 due to financial problems of Better Place.

1.1.3.2 Charging points and charging stations

The network of charging points and charging stations constitutes the backbone of the electricity supply infrastructure for cars developed by Better Place. The majority of car trips are short and will use the charging infrastructure and do not need the battery shift opportunity. From 2010 to spring 2013 around 1400 operational charging points were established. Around half of these, i.e. around 700, are located in public spaces. Of the other half, established in private spaces, around 2/3 are located at businesses and 1/3 are at private homes (Better Place 2013, Jul 2012). The private charging points are used the most. In a large real-life test of infrastructure performance, car use and driving patterns (with over 900.000 test kilometers driven), more than $\frac{3}{4}$ of the electricity was charged through the private chargers and less than $\frac{1}{4}$ (21%) at public chargers (Gurewitsch 2012).

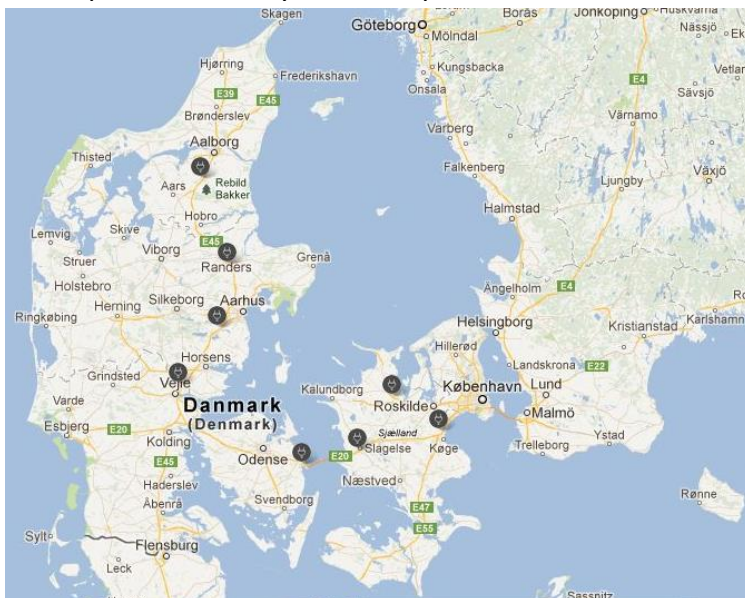
Figure 3: Overview of the Better Place infrastructure in Denmark in 2012. Large dots: Battery switch stations. Small dots: Charging points. Source: Gurewitsch 2012 / Better Place NOC.



The geographical density of public charging points is biggest in the Copenhagen area. There are also charging points in not only Aarhus and Odense (the second and third largest cities of Denmark), but also in more than 40 smaller towns and other relevant places around the country (Better Place 2013, May). Better Place declared that the first nationwide electric car network in Europe was realized in Denmark by December 2012 (Better Place int. 2013).

In addition to the ordinary charging points and stations, eight fast-charging stations were established. They are located primarily along the motorway that connects the four largest towns of Denmark: Copenhagen, Odense Aarhus and Aalborg, see Figure 4.

Figure 4: Better Place fast charging stations in Denmark, May 2013. Source: Better Place, <http://danmark.betterplace.com>, May 2013, map data ©2013 GeoBasis-DE/BKG, Google.



The largest energy company in Denmark, Dong Energy, is co-owner of Better Place and has been a central collaboration partner in the Better Place development, not least on the development of the infrastructure. Dong Energy is owned primarily by the state. In addition to Dong Energy also other energy companies, e.g., Verdo from 2012, delivered electricity and electrical installations to Better Place.

The basis of the Better Place infrastructure technology is developed by Better Place int. in Israel. A considerable, further technical development and tailoring to the local demands in Denmark, including the specific technical and climatic environment, have taken place in Denmark with Better Place Denmark and DONG Energy in a central role (Gurewitsch 2012). The charging points builds on a mix of standard components and specialized components and control technology. Some of the actual manufacturing of the charging point equipment took place in China.

1.1.3.3 Navigation and energy control system

A navigation and energy control system for the users of the electric cars is part of the subscription package of Better Place. The system is called Oscar. It allows the car and the car user to communicate with the Better Place network and provides continuously updated, personalized information. Amongst other things it informs the car user about the status of energy on the batteries, the charging of batteries, and the expected remaining range of kilometers before charging is needed. Moreover it can be used as route planner and for identification of location of charging points and battery switch stations nearby. The Oscar system can be accessed in the car, by smart-phone or over the internet. The system was produced by Better Place. It uses and integrates with a number of the general platforms of IT communication technology in cars, GIS, smartphones, etc.

1.1.4 Network operation centre and integration with the electricity grid

A network operation centre was developed to handle the control and management of the Better Place infrastructure and the electric cars in Denmark. It gathers and distributes the many different types of data information needed for the operation. The network operation centre facilitates the connection between the individual cars and the charging points / battery stations and keeps track of it. Apart from in direction of the car users, the network operation centre also exchanges information with the providers of the electricity grids and the retailers of the electricity. In parallel to Better Place's network operation centre, the actors of the electricity systems worked on developing a data exchange system (data hub) connecting all the information to/from the different actors in the system (see Figure 1).

1.1.5 Marketing, sales, and branding

A systematic work with branding, publicity creation, and a self-confident appearance in public spaces and media constituted an important dimension of the Better Place activities. Better Place was among the most visible electric car solutions in media and public discussions about electric cars in Denmark in 2008-2013, amongst other things due to demonstration activities and systematic use of press releases, press officers, etc. The branding and marketing by Better Place attracted considerable attention to the company as well as to the area of electric cars in general. Apart from in direction of car users, policy makers, possible investors, and collaboration partners

in general, the marketing and sales activities consisted in more specifically targeted efforts e.g. directed at individual municipalities and other public and private businesses that have a car fleet.

Figure 5: Activity in the network operation centre (photo: Better Place, Gurewitsch 2012).



Better Place received attention from design communities and won prizes for its design, partly due to the visual and functional qualities and partly due to its appearance as a system- and sustainability-oriented solution that would improve life (INDEX 2009 and 2013). The consistent use of the blue logo and the blue and white (light-grey) colors in all the equipment ranging from software apps, over information material, to charging points and battery stations, is part of the systematic design and branding. Elements in the shapes of the charging points moreover recur from one type of charging point to another.

The name itself, Better Place, was an important element in the marketing and branding. Alone and in connection with further statements of the identity and goal of Better Place like, e.g. “We want to accelerate the shift to sustainable transport – to make the world a better place”, the name gives an impression of high ethical values and responsibility. By interacting with Better Place, customers and collaboration partners get a feeling that they are part of a responsible activity. By choosing Better Place they can feel that they have themselves made a responsible choice that is good, not only for themselves and Better Place, but for broader society as well. The appealing to peoples’ responsibility is e.g. also found in slogans like: “To all who think before they tank up” and “100% electric – 100% thoughtfulness” (Better Place 2013 web, Rasmussen 2012, Egelund 2012, my translations).

The issue of sustainability was addressed in very general terms by Better Place. It is to a high degree implicitly and unspecified in the branding and sales activities. If one looks into the more specific description of the solution and product the customers got, it was focused primarily on the nice driving experience and the easy, unproblematic and comfortable daily use of the electric cars. Environmental impacts and sustainability improvements were not or only rarely described in any details. The technical specifications about the cars were primarily about the comfort of the car use (size of car, engine, battery, kilometer range, how fast it can accelerate, charging time etc.) (Better Place 2013). They were not about environmental impacts. Apart from that Better Place aimed at giving the customers an impression of nice and unproblematic use of electric cars that is as good as with traditional petrol and diesel cars, another reason for the emphasis on the driving experience instead of on the specific environmental and sustainability impacts can be the primarily fossil-fuel based electricity systems in Denmark.

1.1.6 The electricity – and the CO₂ emissions

Though it was absent from much of the branding and marketing activities of Better Place, the use of electric cars in Denmark today is normally a CO₂-emitting activity. Most of the electricity in the Danish electricity grid is produced by fossil fuels (coal, gas etc.), though renewable energy constitutes a considerable share as well; between 32% and 40% in the latest years (DEA 2012a). In the order of 2/3 of the renewable energy is wind energy, however it is varying considerably from year to year, and from hour to hour.

Accounts from the Danish Energy Agency and Danish Transport Agency show that with the current energy mix in the electricity grid the CO₂ emission from a small electric car is typically around 60 grams CO₂ per kilometer in average. For the medium-sized Renault Fluence it is estimated to be around 83 g/km in 2012 and 69 g/km in 2013 (DTA 2010, Levinsky 2012, Rask 2013).¹ This is smaller emissions than from most traditional cars. However it is not vanishingly small. For comparison the CO₂ emissions from some of the small and most efficient petrol cars on the market today e.g. Fiat 500 0.9, Citroën C1, and VW UP (BlueMotion) are respectively 92, 99, and 95 grams CO₂ per kilometer. Among the most efficient diesel cars are Skoda Fabia 1.2 TDI CR 75PS GreenLine II with 89 g/km and the old record holder Lupo 3L TDI with 81 g/km (VCA 2013, VW 2004).

¹ The difference is probably due to more wind in the calculations for 2013 than for 2012.

The environmental rationale for the electric cars appears stronger if one considers some of the more indirect connections: That the charging of batteries, if intelligent charging and smart grids are further developed, to a higher degree can be scheduled to windy and other energy-surplus hours and moved away from the already existing peak load hours of the electricity systems. Thereby the average CO₂ emission can be reduced. Moreover it can contribute to a buffer and a power pool in the electricity systems that can allow further installation of wind energy plants and other types of fluctuating renewable energy, e.g., solar energy. The environmental rationale for electric cars and for Better Place in Denmark is closely related to the hopes for the electricity grids of the future; especially the plans of installing more wind energy plants and by 2020 have more than 50 % of wind energy in the electricity grids (KEM 2013)². If such change is made, the CO₂ emission from Renault Fluence has been estimated to be around 40 g/km (Levinsky 2012).

1.2 Supporting activities

In the following some of the main supporting activities in the Better Place development will be described briefly. Among the main supporting activities were the financial investments made in Better Place, the strategic collaboration on development of the infrastructure, and the RD&D activities undertaken. The regulatory and institutional support activities are also of central importance for the Better Place development, but will primarily be touched upon in a later paragraph.

1.2.1 Investments

A number of public and private actors invested in Better Place, offered loans or in other ways contributed to the financial basis of Better Place. For the activities in Denmark, a collaboration with the largest Danish energy company, the state-owned Dong Energy, was central financially as well as concerning the contents of the activities. The collaboration began in 2008 and defined a financial basis on 770 million DKK (€103 million Euro) in equity and convertible debt for the initial deployment of their electric car charging network in Denmark (Better Place int. 2008 and 2009). Dong Energy became co-owner of Better Place (a minority share of 17% (Bechsgaard 2013)). The collaboration agreement implied that Dong Energy should assist in the Better Place network

² Another indirect interaction that is not considered here is the perspective of the CO₂ quota scheme and the changes that can appear from moving the emissions from the road transport sector to the electricity sector with its quota limits.

rollout in Denmark and be the preferred supplier of electricity to the network. It also implied that Danes stepped into the management of Better Place in Denmark and internationally.

In 2010, Better Place int. signed an agreement with an HSBC-led investor consortium for new equity financing of \$350 million (€265 million), of these \$125 million alone from HSBC. Among the investors are also Morgan Stanley Investment Management and Lazard Asset Management. They joined existing investors as shareholders of Better Place, among others, Israel Corp., VantagePoint Venture Partners, Ofer Hi-Tech Holdings, and Maniv Energy Capital. In 2011, additional investment of \$200 million (€150 million) was made by amongst other General Electric, UBS AG and a number of the existing shareholders. According to Better Place the investment agreement in 2010 was one of the largest clean-tech investments in history. The value of Better Place after the investment round in 2011 was stated to be €1,7 billion (\$2.25 billion) (Better Place int. 2010, Jan and 2011, Nov). As appears, some of the investors were actors in the energy sector while others were from the general financial sector. In 2012, another \$100 million were invested, primarily by Israel Corp. Since its founding in 2007, Better Place had hereby raised more than \$850 million (€640 million) of equity financing (Godske 2012, Woody 2012).

In 2012, a €40 million loan from the European Investment Bank was made. It was the first credit facility from a financial institution for Better Place. Most of it (approximately €30 million) was to be used to finalize network deployment and fund operations in Denmark. The remaining part was used for similar purposes in Israel (Better Place int. 2012, Aug).

After 2011, Dong Energy stopped its further investments in Better Place. 400 of the 770 million DKK mentioned above had been invested, of these 200 million directly from Dong (Hedevang 2013, EPN 2011). The stop appeared in a period of economic problems for Dong in general. By the bankruptcy in 2013 of Better Place, a considerable part of the investments must be considered lost. In Denmark, the international energy company E.ON bought part of the infrastructure system including 770 charging posts (E.ON 2013, sept). The price has not been available.

1.2.2 Strategic collaboration on development of infrastructure

The strategic collaboration on development of the infrastructure for the electric cars constituted an important supporting activity for development of the Better Place activities. Concerning the integration with the general electricity networks, Dong Energy was also here a central partner. Dong had considerable experience about the electricity systems, energy production and energy

distribution in Denmark and well-established collaboration relations to many of the actors. Apart from Dong Energy, also amongst other Energinet.dk (responsible organization for the electricity grid in general), Danish Energy Association (industry organization for the energy companies) and the national energy authorities participated in this strategic collaboration.

A collaboration with municipalities developed in the period from 2009 to 2013, starting with Copenhagen and some of its' suburb municipalities, and later including the other larger cities, Odense and Aarhus, and smaller cities and countryside municipalities as well. There has been collaboration with in total 52 municipalities about establishment of charging points in public spaces, hence covering more than half of the municipalities in Denmark (representing more than 2/3 of the population). The collaboration with the municipalities created important support for development of the infrastructure for electric cars. It enabled a start of the integration into the traffic and parking infrastructure and created local attention to Better Place and the electric car opportunity in general. Apart from the public infrastructure elements, the collaboration between Better Place and the municipalities in some cases also consisted in interaction about using electric cars in the municipality's car fleet, charging points for the municipalities and their employees, calculation of economic and climatic impacts, car sharing projects, and dialogue with employees and citizens about the use of electric cars (Juil 2012).

1.2.3 RD&D activities

A considerable amount of RD&D activities have taken place in and around Better Place in order to develop the Better Place electric car service and infrastructure. All the activity segments described in Chapter 1.1 have been subject of RD&D activities. They are not just existing solutions that are spread out more widely than earlier, though they on a number of points to some extent build on existing technologies, existing software platforms, etc. In addition to RD&D activities on the individual segments, also development activities, performance tests, etc., on the level of the system as such have been carried out.

On the batteries and the interaction between batteries, cars, charging points, etc., Better Place as mentioned carried out RD&D activities in collaboration with a.o. the Renault-Nissan Alliance, especially Renault, and battery providers as A123 Systems and AESC (Catalyst 2011). On the battery switch stations, the RD&D activities amongst other things concerned development of the robot shuttle to switch the batteries and a certain degree of standardization of the battery mounting and the size and shape of the batteries to be switched. RD&D activities were also carried

out with respect to establishment of automatic communication between the switch station and the car when it is approaching the station and, moreover, with respect to storage of the batteries at the station and establishment of optimal charging conditions, e.g., temperature. With these technology developments, the batteries can be charged in less than an hour if needed and the capacity of the switch stations is 12 batteries per hour.

RD&D activities about steering and optimization of charging processes have been carried out both with respect to charging at the battery switch stations and at the charging points. A considerable share of these activities has taken place in Better Place international rather than in Denmark. This is also the case with the battery switch technology in general. RD&D activities on integration of the charging with the electricity grid have taken place in Denmark. Part of it was done in interaction with Dong Energy and other actors in the Danish electricity system. The network-monitoring and -operation system developed in Denmark was one of the technological milestones for Better Place internationally (Pedersen 2010). Development of intelligent charging that seeks to time the charging to hours where there is surplus of energy in the electricity grids and not in already existing peak load hours for the electricity grid is a part of the RD&D activities. This includes development of steering principles and definition of the communication formats and data exchanges needed. The first steps in this direction have been taken. Further development of the intelligent charging technology is needed a.o.t in order to make it happen in automatic interplay with the loading plans of the energy companies without reducing the quality of the service to the car user (see Figure 6). The local charging capacity is also a challenge and development work and tests have been carried out concerning techniques for avoidance of local overload of the electricity network close to the charging points (Gurewitsch 2012, p. 8-9).

Figure 6: Four levels of smart charging described in the Better Place - Dong collaboration (Westenholz & Rasmussen 2013).

Addressing smart charging on four levels

- Can prioritize and plan charging of home charging according to actual consumption in the home to avoid tripping the breaker/fuse
 - Can prioritize and plan charging of multiple electric vehicles connected to the same parking lot according the local capacity and individual customer need (empty vs. full customer etc.)
 - Can charge the electric vehicles according to the availability of capacity in the regional distribution grid (grid tariffs)
 - Can charge the electric vehicles according to the availability of electricity (spot prices) in the overall Nordic electricity system
- Power Hub integration

Among the collaboration partners on charging technology are also Gamatronic Electronic Industries, LTD and Ariel University, Israel (Kuperman et al. 2010). Moreover, a collaboration with

GE on development of standard-based charging point technology and roaming was established. This collaboration also included a pilot programme for battery financing (Better Place int. 2010).

Concerning the navigation and energy control system for the car users, RD&D activities have taken place both in Denmark and abroad. Collaboration with the supplier of automotive component systems Continental on development of an in-car software system, building on an existing platform from Continental, was part of the activities (Better Place int. 2009, sept).

Public RD&D support

A number of publicly funded RD&D projects in Denmark and internationally supported the Better Place solution. In Denmark, an experimental scheme for electric cars was established by the Government in 2008 with 35 million DKK for practical experiments concerning use of electric cars and infrastructure in the period 2008-2012. The scheme is continued with 15 million DKK for the period 2013-2015 (DEA 2012b).³ Better Place received funding from this scheme for a solution validation test of the practical use of electric cars in connection to the charging infrastructure and battery switch stations. Moreover, they received funding for a performance test of the Better Place infrastructure (DEA 2013, Gurewitsch 2012). In addition to Better Place itself, a number of the municipalities that Better Place collaborates with received funding from the program.

The general public energy RD&D programmes in Denmark in the same period also funded a number of RD&D projects on electric vehicle systems, infrastructure and smart grid integration. According to a search in the database over the projects of the energy RD&D programmes (energiforskning.dk) and various project materials, Better Place was not among the formalized project partners in any of these projects. Their close collaboration partner, however, Dong Energy has been involved in a number of them, not least the large Edison project that aimed at developing system solutions and technologies for electric vehicles and their integration with electricity systems with fluctuating renewable energy. Edison ran from 2009 to 2013 and had a budget on almost 50 million DKK (Energiforskning.dk 2013, Edison 2013). Better Place played smaller roles in a few projects, e.g., the Better Place solution was involved in an interoperability test of different charging spots in the Edison project and hereby as some of the first in the world demonstrated roaming-based interoperability for electric cars (Saabye 2011, TWC 2011).

A test center for compatibility and interoperability between charging points and electric cars, the Nordic EV Interoperability Center (NEVIC), was established in 2011 at the Technical University of

³ From 2013, the scheme also covers plug-in hybrid cars.

Denmark. This was done in cooperation with Better Place and two other operators, Clever and CleanCharge, and the industry organisation Danish Electric Vehicle Alliance. Funding comes from EU Structural Funds, Region Zealand and the Capital Region of Denmark (CCC 2011, NEVIC 2012). The NEVIC center offers the operators interoperability tests within and beyond the limits of the standards and pre-standards. Combinations of EVs, cables, plugs and charging posts can be tested to confirm interoperability. Test procedures and methods are ready to test e.g. new EVs on existing charging posts, new cable cord sets, new charging posts on existing EVs, etc. The NEVIC center has developed simulators where the behavior of equipment can be tested to, and beyond, the limits of the standards.

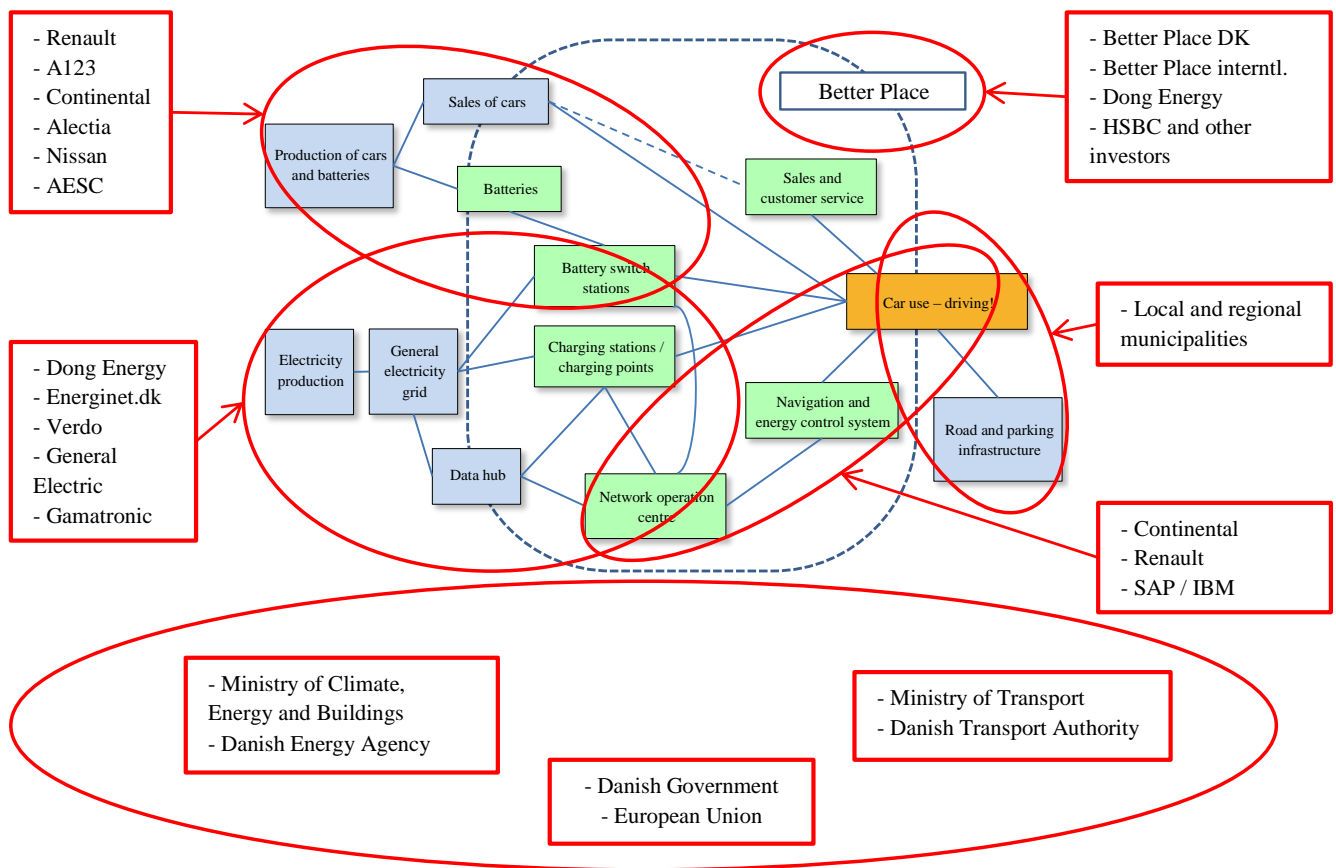
RD&D projects with funding from the European Union supported the Better Place development. The ELVIRE research project led by Continental aimed at developing on-board communication and information system connecting the energy management in the car with the electricity and road infrastructure systems (Auliac 2010). It ran from 2010-2013. The EASYBAT research project from 2011-2013 focused on the battery switch technology, especially the insertion and removal of the batteries in the cars. The project was coordinated by Better Place (Israel). Of the budget of 3,7 million euro, 2,2 million were funded by EU (EU Cordis 2013). Both projects involved 11 partners, companies, research organisations, consultancy companies etc. Renault, Continental and Better Place (Israel) participated in both.

Better Place (Denmark) coordinated the project “Greening European Transportation Infrastructure for Electric Vehicles” under the European Commission’s TEN-T program that dedicates financial support towards the realisation of important transport infrastructure projects in EU. The project aimed at analyzing and demonstrating deployment of integrated battery recharging and switching infrastructure that allows for long distance travels. The first battery switch station in Denmark and one in Amsterdam were part of this project. It ran from 2010 to 2012 and had a budget on 9.9 million Euro of which half is EU funding (TEN-T EA 2011).

In addition, Better Place (Denmark) participated in the on-going sustainable mobility project, “Green eMotion” that is part of the European Commission’s Green Car Initiative (Better Place int. 2012, Aug). In this, Better Place was involved in description of models for user services and interaction used in the ICT solutions for electromobility. Moreover they contributed to a strategy model for promotion of electric vehicles in European cities and collaborated with the regional municipality of the island Bornholm about charging infrastructure for a car sharing service and (Green eMotion 2012, Helms and Clausen 2012, p. 38-41; Green About 2013).

Apart from the technical contents of the publicly funded RD&D projects, one of the outcomes for Better Place was the visibility created through the projects. No complete account of the total amount of public RD&D funding of the Better Place development has been available, however it is judged that the funding from national programmes is in the order of a couple of million Danish kroner max and considerably smaller than the funding in the EU projects which is judged to be in the order of 60 million Danish kroner⁴. The public funding is smaller than the several hundred millions Danish kroner that are invested in Better Place by other investors.

Figure 7: Actors in the different parts of the Better Place value chain. (For simplicity reasons, Better Place itself is only mentioned in the top box to the right and not in the four other boxes (left and right) where Better Place of course also is involved.)



⁴ This figure is calculated as 100% of the public funding in the two European projects led by Better Place (Easybat and Greening European Transportation Infrastructure for Electric Vehicles) plus smaller amounts from the ELVIRE and Green eMotion projects. See also DTA 2011.

1.3 Actors

In sum up of the descriptions on previous pages, Figure 7 gives an overview of the identified main actors and collaboration partners in the different parts of the value chain in the Better Place case. In addition, the figure shows main actors behind the Better Place activities as such in Denmark and the policy actors and public authorities that played central roles for the developments. The set of actors shown is not complete. Many other actors have been involved.

1.4 Value chain governance structure

The value chain in the Better Place case reflects the relational value chain governance structure, where the networks are characterized by complex interactions between suppliers and users and mutual dependencies often appear. The situation is however highly complex and not stabilized. On some points, e.g., plugs and other charging components and energy measuring data exchange, tendencies to more modular value chain structure are seen.

2 Key technologies and maturity

In sum up of the above, the following key technologies can be considered of special importance for the further development of electric mobility following the Better Place model.

- **Basic charging network:** Emergent; initial application of network in full-scale.
- **Intelligent charging systems:** Experimental and emergent; first experiences and real-life applications are made; further development must be expected.
- **Smart-grids:** Experimental and emergent; further development needed (including definition of technical and economic signals and data exchange formats for intelligent charging and for greening of the electricity production).
- **Communication system for the car user (energy control, navigation, payment, etc.):** Emergent; initial application experiences on full system level; further development to be expected.
- **Open access technology and roaming systems:** Emergent and experimental; initial application experience; further development to be expected, still limitations in scope (e.g. international roaming).

- **Battery switch technology (battery switch stations and cars with switchable batteries):** Emergent; initial application experiences; further development is needed a.o.t. more car models (than one) and a standardization supported by a number manufacturers of cars and batteries.
- **Fast-charging technology and local electricity networks that can support it:** Emergent, some application, further development is needed: faster; especially if widely implemented it will be a considerably challenge for the electricity networks supporting them.

It shall be noted that all the mentioned key technologies include technical, socio-organisational and economic dimensions. The technologies imply radical, qualitative changes and not only incremental improvements of existing systems. None of them are fully mature and dominating designs are not stabilized. The bankruptcy of Better Place is part of the evidence for the latter conclusion.

For completeness reasons, electric cars and batteries shall be mentioned here as well, though they are dealt with more in-depth by other studies.

- **Electric cars:** Growing market application, still not widespread and fully mature; performance has improved (more reliable and well-functioning); following the traditional path and dominant design of road transport and mobility by car; prices needs to be reduced in the coming years
- **Batteries:** Emergent; growing market application; durability and performance to be improved and prices to be reduced in the coming years

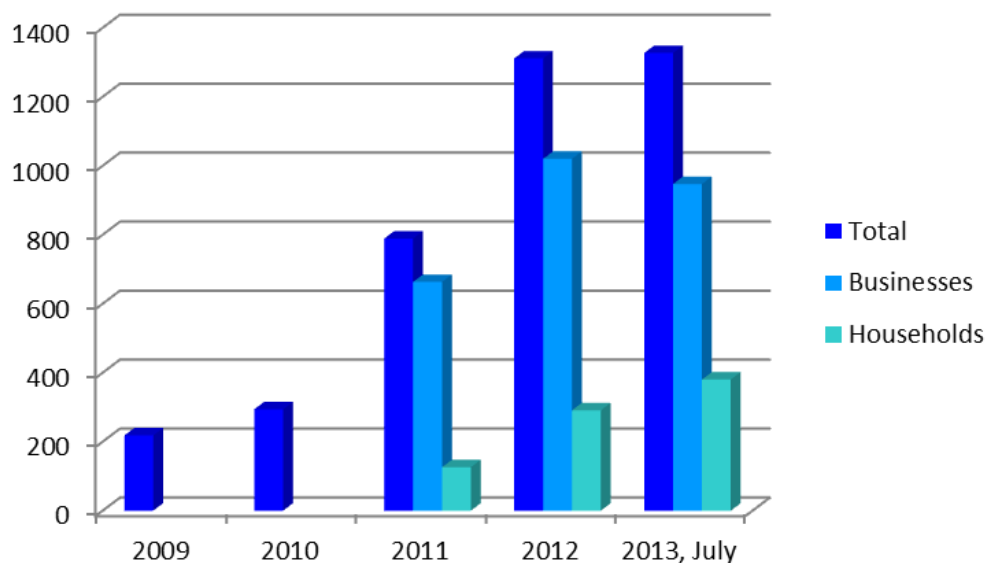
3 Market characteristics

The market in focus for Better Place was the traditional market of small to family-sized cars, that is, cars for personal transport by households or businesses' transport of individuals and small groups of persons. Emphasis is on satisfying the mobility needs and driving patterns that are normal for traditional cars. Hence there is not focus on city driving only or similar more limited types of car uses. Neither is there focus on micro cars. The number of subscribers to Better Place was in spring 2013 around 500. Renault Fluence Z.E. constituted a considerable share of the cars used by the Better Place subscribers with 219 registered by spring 2013 (to this come a number of

demonstration cars etc. owned by Renault retailers and Better Place) (Arent 2013). Smaller cars and delivery vans constituted around 1/3 of the cars (Linnet 2013).

The number of electric cars in Denmark increased significantly in 2010-2012. The number of person cars is now around 1300, see figure. To this come around 180 small vans. Most of the owners of the electric cars are public and private businesses. Households' share of the total number of electric cars has increased over the latest years. Around ¼ it owned by households. The number of electric cars constitutes around 0,06 % of the more than 2,2 million cars in Denmark. Though still a small number, it makes it one of the highest densities in Europe (surpassed by Norway though) (Ingemann / Statistics Denmark 2013, Weeda et al. 2012).

Figure 8: Electric cars in Denmark (Statistics Denmark, Motorregistret (SKAT)). Distribution of the ownership between businesses and households is showed for 2011-2013. The figure shows person cars only, not vans.



While the number of charging points earlier should be counted in 10s, the charging network has with Better Place become considerably more developed and dense. With the around 1400 charging points, the number shall now be counted in hundreds and even thousands. This development in the number of charging points makes a significant qualitative shift in the use of the network and the electric cars.

Better Place is one of two of such networks that have been established in Denmark. The other is the Clever network (earlier called ChoosEV). The Clever network by second half of 2012 had

around 300 charging points and 60 fast charging stations established and around 400 cars under its administration (Kirketerp-Møller 2012). In addition to Better Place and Clever, there are a few other smaller networks and suppliers of charging points.

3.1 Geographical scope

Most of the electric cars appear in the Copenhagen area. By the end of 2011 almost half of the electric cars in Denmark were registered in the area of the municipality Copenhagen City (the central part of the Copenhagen area) (Ritzau 2011). The density is probably more spread out now, but still 53% of the electric cars are registered in the Copenhagen region (Region Hovedstaden 2013, p. 23). In Copenhagen Municipality 129 public charging points are established and there is parking and charging space for 226 electric cars (Københavns Kommune 2013; the figures do not only include Better Place). Most of them were established in 2011-2013.

Public procurement by local and regional municipalities has played a considerable role in the developments. The municipalities constitute a considerable group of users of the electric cars. The 29 municipalities in the Copenhagen region in 2013 in total have 274 registered electric cars. This constitutes 18% of all electric cars in Denmark and 8% of the total car fleet of the 29 municipalities (Region Hovedstaden 2013, p. 24). Some municipalities made a strategic decision of only buying electric cars for their car fleets (in some cases hydrogen cars as well). Among these are e.g. Copenhagen City, from 2011 (Københavns Kommune 2012).

Better Place focused its geographical rollout plans on areas that can be seen as “transportation islands”, largely self-contained areas that are receptive to electric cars (Hammer 2010). Denmark was considered such an area. The geographical scope of Better Place in Denmark was to establish a nationwide charging and battery-shift infrastructure that can cover the every-day mobility needs of most car users. The Copenhagen area has been a natural place to start in establishing the network. Around one third of the population is living there. However the infrastructure is starting to appear as nationwide. The charging points are as mentioned in Chapter 1 spread out over the country, with the highest densities in the larger towns and along the intercity motorways.

Due to financial problems, Better Place in Denmark in 2013 concentrated on further development in the two largest towns, Copenhagen and Aarhus, and reduced its efforts in other places. Internationally, it focused its market activities on its’ two main countries, Israel and Denmark. A started development of infrastructure in Australia was stopped. The Better Place network in

Hawaii consisting of around 130 charging points was launched in 2012. In the first months of 2013 it was sold to the Oregon-based provider of electric vehicle charging management OpConnect due to the financial problems of Better Place, leaving Israel and Denmark as the primary markets for Better Place. After the bankruptcy of Better Place, the activities in Israel were acquired by The Sunrise group. In Denmark, the international energy company E.ON has taken over a major part of the network including 770 charging posts and intellectual property rights to elements of the technology.

Figure 9: Better Place charging posts in Copenhagen summer 2013, shortly after the bankruptcy. Note the red light signaling out of service and the absence of electric cars. Photo: Mads Borup



4 Institutional context

An important driving force for Better Place and other electric car activities in Denmark in recent years has been the renewed political attention to electric cars that appeared in the second half of the 00s. This was connected to a general rise in attention to the transport sector as a part of the climate problems in the European Union and in a number of countries (Geerken & Borup 2009). In

Denmark, the government established a 'green transport vision' as part of the long term transport policy (Danish Government 2008).

In parallel with the earlier mentioned national experimental scheme for electrical vehicles, a row of other policy and institutional initiatives are developed. A number of institutional actors are involved. In the Ministry of Transport (Danish Transport Authority) as well as in the Ministry of Climate and Energy (Danish Energy Agency) new units were established in order to develop strategies and analyse the situation concerning electric cars and other alternatives to the oil-based fuels in the road transport. They initiated assessment work on the opportunities and challenges of integration of electric cars in the road transport sector and in the electricity systems (DTA 2010, DEA 2010 and 2011). Energinet.dk, the institution responsible in general for the electricity networks in Denmark, developed analyses of the integration of electric cars in networks including models for the functional units, responsibilities, technical requirements, data exchange formats, etc. in connection to the charging infrastructure (Energinet.dk 2010). In parallel to this, a number of energy companies, including Dong Energy, and the association of energy companies, Danish Energy Association, developed their analyses and suggestions for the working of the charging infrastructure (see e.g. the Edison project 2009-2013, Danish Energy Association).

The different institutional initiatives are not disconnected, but often developed as a reaction to each other and to the general policy. Usually they are made in dialog with each other to some degree. The political attention and the efforts by the institutional actors created a general positive attitude among the actors and willingness to going constructively into interaction with and around Better Place's solutions.

An outcome of the work by the authorities and other institutional actors was identification of the need for harmonization and standardization of the charging solutions with respect to (DEA 1011, p. 30 and p. 74; Energinet.dk 2010 p. 2-8):

- Charging plugs and cables
- Communication between car and charging point
- Communication between charging point and operator
- Open access to charging points for all car users independently of which operator they subscribe to (roaming, nationally and internationally) ; includes payment identification

The EU initiated similar standardization work (EC 2010). The formalized standardization work is in Denmark organized by Dansk Standard in the Standardization committee for electric cars (S-454) with connection to the international and European standardization developments on electric road vehicles (a.o. IEC TC69, CLC TC69X, and ISO TC 22/SC 21) and on communication in electricity systems (IEC 61850-7-420). Better Place participated in this. The standardization needs also concern communication for 'intelligent charging' where the charging is flexible and carried out according to varying prices and capacities in the electricity systems, however the standardization processes on this issue are expected to take longer time than on the points mentioned above and are not established yet.

The interoperability between different suppliers of charging services and the open access for the car users to all charging points are also among the requirements from municipalities that collaborate with Better Place on charging and parking places for electric cars (Aalborg Kommune 2012).

An exemption from tax on electric cars is established. The exemption covers registration tax (105%-180%, paid when you purchase a car) and the annual vehicle excise duty. The tax exemption is not permanent and has been renewed in 2008 and 2012. The current exemption is in force until the end of 2015 (Danish Government 2012b).

In the national energy agreement from spring 2012, DKK 70 million are allocated to support establishing of more charging posts for electric cars, infrastructure for hydrogen cars and for gas in heavy transport in the years 2013-2015. Of the 70 million DKK, 40 million are expected to go to the charging posts (Danish Government 2012a, KEM 2013). The national strategy for the promotion of energy efficient vehicles is planned to be revised by the parliament in 2013.

An exemption from energy tax (actually: refunding of energy tax) for companies when they recharge electric cars (through charging points, battery stations, fast-charge stations, etc.) is established and runs until the end of 2015 (Danish Government 2012c).

A possibility for authorities for establishing parking spaces for electric cars only is made in the legislation (Lewinsky 2012). It has been suggested to change the legislation also for enabling exemption from parking fee in the cities for electric cars. An exemption from parking fee in Copenhagen was established for a couple of years, but by the end of 2011 it was not renewed

(Praëm 2012). In summer 2013, the Government initiated work on tenders concerning installation of charging points at the manned pull-ups along the motorways (TRM 2013).

The institutional context also in other ways played a role for the Better Place development. The initial contact between Better Place and Dong Energy was created by Invest In Denmark which is a part of the Ministry of Foreign Affairs that supports foreign investors and companies to do business in Denmark (Better Place int. 2008). Moreover, as mentioned, the local and regional municipalities supported the developments. The Capital Region and the network of municipalities in the larger Copenhagen area have established a joint climate strategy in which the region aims at becoming leading electric car region. A support secretariat “Copenhagen Electric – the regional electric car secretariat” is established (Region Hovedstaden 2013).

5 Path dependencies and path creations

In the following, central aspects of the path dependencies, deviations created and opportunities for future developments are discussed. The Better Place solution is to a considerable degree dependent on especially two existing paths: the road transport systems and the electricity systems. Concerning road transport, Better Place is continuing the path for personal mobility by car. With its focus on making it as easy and unproblematic as possible for the drivers to use the electric cars and an emphasis of avoidance of changes in driving patterns compared to normal (petrol and diesel) cars, there is no challenging of the existing road transport path in general. The connection with the relatively large, family-sized car, especially Renault Fluence Z.E., and not with e.g. micro cars and city cars, is in line with this picture. A dependency on the development paths and value chains of the car industry moreover appeared as Better Place had close collaboration with traditional car manufacturers and sub-suppliers in the car industry.

The dependency on fossil-based fuels and the oil-based regime in road transport sectors have not been broken by Better Place and the other electric car activities in Denmark. Not yet at least. However, an important outcome of the activities so far is that they have shown that there is an alternative to the oil-based regime within road transport and that the alternative is becoming more and more realistic. The establishment of the basic, country-wide infrastructure for the electric cars and the increased visibility in the streets and in the media are central for this.

Speaking still on a general level, Better Place is dependent on the path of electricity networks as central and more and more pervasive societal energy infrastructure with threads almost everywhere. The electric car developments contribute to a further expansion of the working areas for the electricity systems and of the markets for electricity producers and traders.

Concerning sustainability challenges and environment, the case shows that the electric car systems do not directly eliminate the environmental impacts from road transport in a country like Denmark. They primarily move the environmental emissions from the transport systems to the electricity systems. A further reduction of the environmental impacts is highly dependent on the development path of the electricity systems, of the electricity production and of the synergies there might be developed in the interplay between the charging of batteries and the renewable energy production. The plans about 50% wind energy in the electricity systems in Denmark by 2020 are of central importance in this connection.

Further development of smart charging is crucial. The current charging patterns reinforce rather than reduce peak-load problems in the electricity nets. Much of the charging appears in the 'cooking peak' in late afternoon and early evening hours and not when surplus energy is available, e.g., after midnight or when it is windy. If electric car systems shall play a role in reducing energy surplus and peak-load problems and hence appear as a buffer in the electricity systems, a significant and intelligent price differentiation mechanism must be enabled in the systems (cf. Figure 6 and the four levels of smart charging). This is both a technical and regulatory challenge.

New role distributions

On a number of points, the Better Place case shows creations of new actor roles and role distributions between actors. The new roles often mark a deviation from the existing paths. Here three of the most important deviations shall be mentioned. Firstly, the actor role of Better Place itself as a system oriented provider of energy service for electric car users is new. Not only is it a new model of business for Better Place and its customers/subscribers. It is also a new type of actor in-between the electricity systems and the end users of the electricity. The traditional actors of the electricity systems, e.g., network operators, authorities, energy producers and energy retailers will need to relate to this new type of actor. In many cases, this implies development of new interaction patterns, including development of technical interfaces and communication formats. To what extent the data communication will be gathered in one, central data hub or happen through a more decentralized communication system can be important for the further

developments. In addition to the electricity systems, the new actor type also implies changes for authorities and other actors in the road transport systems, e.g. with respect to charging and parking spaces.

It shall be noted that the subscription-based business model with free and unlimited electricity for the subscribers and no direct connection between the amount of electricity used and the costs for the car users, does not support energy-saving behavior by the car user. On the contrary, it encourages more electricity consumption and expands the market for the electricity producers and retailers.

Secondly, the Better Place case shows a new role distribution with respect to ownership and responsibility of the electricity infrastructure close to consumers. While earlier establishments of electricity infrastructure often have been considered a public responsibility, it is in the Better Place case a private company that owns the local infrastructure and is responsible for it. This means that the use of the infrastructure is vulnerable and can be unreliable in others ways than if it had been a public effort.

Thirdly and finally, the battery switch technology with stronger distinction between the battery and the car suggested a change in the role distribution in the car supply value chain and a redefinition of what is considered an integrated part of the car and what is loose equipment attached. When the batteries are bought separately, the car manufactures and car retailers are less likely to earn money on them. It can be seen as a little step in direction away from the path dependency in the car value chain with the car manufacturers as completely central, in favor of a growing importance of the relation between the service supplier, the battery suppliers and the users. The fate of the battery switch technology is however highly uncertain after the bankruptcy of Better Place. With the battery switch stations, the Better Place solution had the unique feature of having three parallel systems for getting fresh batteries to the car users: normal and fast charging points and battery switch stations. Due to added value in connection with longer trips especially, this three-pillar infrastructure system might have resulted in an all-in-all more robust and useful infrastructure for the users had the bankruptcy not occurred. The parallel systems also created a degree of competition between the solutions for providing fresh batteries that may have qualified the development.

The parallel charging systems is not the only place where competition is created and supported in the Better Place case. The creation of competition is often an intentional strategy of the

authorities and policy makers. It is not a coincidence. It ensures a constructive competition between the solutions and an avoidance of being stuck with only one supplier that can use its monopoly position and to a large degree determine the price of the solutions delivered. For example, it is not a coincidence that there are two, and not only one, infrastructure systems established in parallel (Clever and Better Place; plus some smaller ones). Similarly, it is also intentionally sought to have many car suppliers delivering cars, and not only one supplier.

Competition is also created by the demand of open access to the charging points no matter which network supplier they come from. The standardization of charging methods and plugs plays an important role in this connection. A degree of standardization of charging plugs is moreover established. It can be important for the future development that there is continued attention to standardization and agreement on the plugs, e.g. in connection to new two-in-one plugs. The principle of equal access for all to charge from the public charging points is similarly important to maintain. To which extent competition is ensured in the future might have important influence on how the electric car area in general will develop and to what extent it will be a realistic alternative to other kinds of transport.

Finally, it shall be mentioned that the case is one of the few examples of the energy sector and the road transport sector actually working together on creating a move away from oil-based systems. This collaboration is driven by policy and the case is one of few examples of energy policy and transport policy being connected and coordinated in Denmark. This coordination is not easy and unproblematic. There is tradition for two separate paths of energy policy and of transport policy, including different paces and time intervals for updating and refining of the policy efforts and separate lines of authorities, regulation frameworks, etc. For example, some of the transport regulation, e.g., parking legislation and legislation related to enabling the possibility of charging points at pull-ups along the motorways developed slowly and relatively late in the processes. The energy policy has in general been more in lead, though also more regulatory development is needed here, not least on smart-grid principles, price systems and other incentives for charging when surplus of renewable energy.

6 Conclusion

Better Place was a central and leading actor in the development of electric mobility area in Denmark in the period 2008 to 2013. It connected actors of the energy systems, the road transport systems and the car supply systems and positioned itself in a central role as e-car service provider and infrastructure operator. The company established a charging infrastructure that with more than 1000 charging points and charging locations also outside the major cities started to appear as countrywide. This is one of the first places in the world where such countrywide e-car infrastructure is seen. The parallel development of a similar infrastructure by the other major e-car operator in Denmark, Clever, reinforces this picture. The bankruptcy of Better Place in 2013 put a hold on the developments, at least for a while, and the international energy company E.ON has taken over major parts of the infrastructure. The battery switch technology is not taken over and its future is uncertain. The substantial investments made in Better Place by private and public actors must be considered lost to a large degree.

The electric mobility developments in Denmark were enabled by policy efforts on national and sectorial level. It is one of few examples of policies in the energy area and in the road transport area actually being coordinated and worked together in order to create a move away from oil-based road transport. The opportunity of integrating more wind energy in the energy systems is a central argument in the policy development. In addition to national and sector-oriented policy, policy efforts by local and regional municipalities also supported the developments through procurement of e-cars and designation of spaces for charging & parking. Among the regulatory and institutional support efforts are moreover the tax exemption of e-cars, the establishment of a model of functional units and data exchange formats in the integration of electricity networks and e-car systems, and the requirements of open access for all users to the public charging points and standardization of charging system e.g. concerning the plugs. A degree of competition between different operators and suppliers of energy charging infrastructure is established and can be seen as fruitful for the developments.

The Better Place developments built on and continued the established path of road transportation by car and moreover continued and expanded the path of the electricity systems as central and pervasive in society. Sustainability and climate issues most often only appeared implicitly and unspecified in the Better Place activities. The fact that much of the electricity in the Danish electricity nets is produced from unsustainable, climate damaging sources was usually not addressed in the discussions or in the interaction with the consumers. If a move away from climate

damaging energy and transport systems shall be made in the future it can be important that the climate impacts are addressed more clearly. The charging patterns established do not fit the hours of surplus wind energy and are so far reinforcing instead of solving the peak capacity problems of the electricity systems. Considerably further development of intelligent charging and smart grid technologies are needed if a positive interplay between wind power and e-mobility shall be established.

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Currency exchange rates used: 1 euro = 7,46 Danish kroner, 1 US \$ = 5,63 Danish kroner.