Lessons Learned

By Better Place

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Executive Summary

This report is an evaluation of the Better Place concept of battery switching and its business model applied in Denmark. As part of Green eMotion the report brings forward the most important learnings that Better Place has gained over the years building a fully operational network of EV infrastructure on 100% private initiative.

The report also bring forward a number of recommendations for policy makers based on the experiences gained all the way from building a service provider business in Denmark, developing and deploying a national network of infrastructure and marketing and selling the concept in collaboration with local Renault dealerships across the country.

Since starting in Denmark in 2008 the company has slowly grown from a start-up with nothing more than an idea to a fully operational service provider in 2012. The national Danish network of 18 Battery Switch Stations (BSS) and approximately 400 charge spots (CS) were deployed 2010-2012. The network provided a solid foundation for gathering consumer data, testing real life experiences of EV driving and analyzing the market oriented approach. More than 2M eKM were logged through the Better Place Network Operations Centre and more than 20.000 switches were performed on the network of BSS.

In 21 months the Amsterdam Taxi Project achieved to 237,220 km and 3.248 switches at the station. The maximum km range per week is of 2.412 km per car. In a year the average km per car would be approximately 80.000 km per car.

The case of Denmark and the taxi project in Netherlands was concrete evidence of a technology that worked in practice with a network comparable to the performance of ICE cars. More importantly, customer feedback showed that Better Place customers were very satisfied with driving electric and switching battery on longer trips.

In the aftermath of the liquidation of Better Place, the operations of charge spots and battery switch stations continue in Israel. In Denmark Europe’s largest energy company E.On has acquired the network. Moreover, recent developments in China and the US (Tesla) shows that the concept of battery switching continue in different models.

1. Introduction

The last couple of years we have seen an expansion in the number of highway capable EVs available to the mass market. Many auto manufacturers are these years adding their first EV models to their fleets and companies like Renault and Nissan have 2-4 EV models in their lineup. The auto manufacturers are electrifying their fleets with innovative models and it is anticipated that the EV market will grow swiftly, with a compound annual growth rate of 20-30% between 2013 and 2020. Europe is expected to account for more than 25 % of global EVs sales in 2020. This assumes the availability of early adopter consumers and governments for promoting electric vehicle programmes. The predictions are that there will be a 10 % penetration of electric vehicles in 2020. Europe with its excellent research base on components, electronics, microsystems, smart systems integration, power electronics and software architecture can make a difference and catch a significant market share of the electric mobility market.

Electricity as an alternative to traditional transportation energy is becoming a near term reality for Europe. The market for EVs in Europe is growing as the users look for cleaner, more efficient vehicles. The European industry is well placed to be a major supplier of EV components and vehicles, not only in Europe but also internationally. To achieve the timely and effective commercialization of EVs, national governments, EC and industry must work together on ensuring that the necessary steps are taken. Green eMotion and Better Place have been two of the most important initiatives in that respect, each contributing with different steps in the process of bringing EVs to the mass market. However, many obstacles lie ahead and hopefully this report can bring forward some of the learnings that Better Place has gained as a private initiative.

Throughout almost six years of operations as a company solely committed to build a prosperous EV network operator business, the company has worked closely together with important stakeholders in the regulatory and political sphere. Below is given an overview of recommendations to regulators and politicians at local, national and European level:

1.1 Recommendations for future regulation and public support

The experience gathered during the implementation stage of the Better Place network as well as from the user data on the period of operation show that the battery switch station technology is mature and ready for the mass market. This is also evident after having accomplished 18 battery switch station in Denmark, which are being used every day by costumers switching their batteries. Much learning has been gathered in this process, both while implementing the battery switch station, but also in the pre-implementation stage of locating each site and acquiring all necessary permits.

The deployment, installation and operation of charging infrastructure require multiple permits, certifications and authorizations from a multitude of authorities. Each Member State sets its own regulatory permitting requirements and these are later adhered to by all the potential companies seeking to provide charging services. For example, for a battery switch station, four different types of permits might be required: building permits, which may take over 18 months to obtain from the various municipalities; environmental permits, which may include a requirement for an environmental assessment, a process which could take up to a year to complete; safety permits above and in addition to the EU and ISO standards; and operational permits, which are required either for the mere operation of the infrastructure, or for parts of it, such as, for example, the meter within the battery switch station

In comparison with deploying a gas station it is important to conclude here that the permitting process is much less complicated as a battery switch station does not contain 'fuels' other than the electricity for operation and charging of the batteries. Therefore it will be possible to implement battery switch stations in a number of sites were petrol stations couldn't be implemented.

The deployment of charge spot may also require a number of permits and authorization, namely building and safety permits. The requirement of building permits is especially problematic in common buildings, where tenants may need authorization from the building residential board, or even from a majority of the neighbors, in order to submit a request for building permit for charge spot in their own private parking spot, inside the common parking lot.

In general, the permitting ecosystem for charging infrastructure is an elaborate one, which include multiple requirements, and which poses hurdles in the timely deployment of infrastructure.

1.2 Regulation of services

The regulation of services can also create barriers to market entry. In some of the markets, due to lacking specific legislation to govern this ecosystem, operators of charging infrastructure may be required to adhere to specific regulations that were designed and targeted at power distributors, or utilities, rather than companies who operate in electric vehicle charging infrastructure.

Operators are required to provide multiple permits for each element of their solution; in addition they are governed by legislation that is targeted at other players, such as utilities, or transmitters, thereby adding another load of regulatory requirements. Moreover, these regulations and legislation span across the lifetime of the business, from pre-deployment, through operational status; and they relate to all aspects of the product: the meter, the deployment, the operation, the communication protocol, the data storage, the energy provided, the billing, and others. Altogether, this complicated web of requirements and prerequisites creates an entry barrier to the market that may be hard to surpass for the majority of the companies that hope of becoming a wide ranging operator, rather than a local one.

1.3 Recommendations for local authorities

Based on the studies which have been carried out the following recommendations for local authorities have been concluded:

Work closely with the local distribution system operators, DSOs, to pre-identify urban locations for deployment of in electric vehicle infrastructure.

Integrate the deployment of charging infrastructure strategy into the long-term municipal construction planning.

Anchor the planning of charging infrastructure across all municipal departments who are affected or somehow involved in the processes to ensure effective procedures.

Assist with the coordination between different stakeholders who are influenced by the deployment planning.

Show the good example by adopting in electric vehicles in the municipal fleet of vehicles and by raising the awareness of citizens through in electric vehicle campaigns and branding of in electric vehicles as a mean to greener transportation.

Support for quick processing of permits for deployment of charging infrastructure

Support in terms of investments in public charging infrastructure

1.4 Recommendations for national level

In addition to the above stated recommendations for local authorities, the following recommendations have been developed on a Member State level:

Clear incentives should be given to consumers purchasing in electric vehicles to assist the upscale of e-mobility during the transition phase. Once in electric vehicles reach a certain number incentives should be lowered.

Incentives should be given to companies and employees who choose in electric vehicles as their company cars.

Free parking should be given to in electric vehicles during a transition phase to greener transportation. Such legal ground should be established to ensure that all municipalities can differentiate parking charge based on the environmental impact the vehicle causes.

Special parking places should be reserved for in electric vehicles in public parking sites to allow for instalment of charging infrastructure. Such measures will need the necessary legislation to be in place, which is not the case today.

It could be considered if incentives should also be given to people employed in the public sector who would use their electric vehicle during working hours instead of an ICEV.

In order to develop a sustainable smart charging infrastructure – new investments should be given to develop a charging infrastructure that can support intelligent charging.

The utilities have an important role in the development of intelligent smart grid solutions, which should be rewarded by government incentives during the initial phases.

There is a need for a clear strategy on the uptake of in electric vehicle s in each Member State. This would require collaboration between relevant ministries, politicians, research institutions and the energy sector as well as stakeholders within the in electric vehicle ecosystem to decide on a collaborative approach.

1.5 Recommendations on a European level

Technologies for in electric vehicles are mature. Both in terms of charge spots, battery switch stations and the communication requirements that will enable the operation and monitoring of the network. In the case of Denmark in electric vehicles have entered the streets in 2012/2013 in higher volumes and prices are very attractive compared to ICEV. However to build infrastructure in a pan-European perspective requires strong public support.

Based on Better Place experiences the following recommendations apply:

Continue to fund innovations and new technologies to aid the transition to greener transportation. By funding such projects as Green eMotion it will be possible to bridge the gap between R&D and actual full market penetration.

Focus on electrification of road transport including for long distance driving (i.e. alternative re-fuelling stations such as fast charging stations and battery switch stations) and use the limited available sustainable biofuels only in transport modes where no feasible alternatives for oil are available.

Mitigate regulatory hurdles for the deployment of in electric vehicle infrastructure and create incentives for the roll out of in electric vehicle-charging facilities, including those to facilitate long distance driving.

Create incentives for charging solutions of in electric vehicles that allow shifting electricity load in time (as opposed to unmanaged charging) to minimize additional required investments to the electricity infrastructure and maximize the uptake of renewable electricity in the EU; smart charging and smart grids.

Strong push for quick standardization of interfaces between the cars and the infrastructure to allow interchange ability, interoperability and safety on batteries, connectors, charge spots and battery switch stations.

The European Commission should intervene and select one single plug for Europe (avoiding different standards in different Member States as currently proposed by some the standard committees).

There should be a strong call for Mode 3 charging to be the only way to charge in electric vehicles, hereby ensuring that no unmanaged load is created once the mass market is in place. Such measures are important in order to benefit from the smart grids and to enable the integration of renewable energy.

Regulation should be in place to secure that all charging will be done via a Central Network Operator (Mode 3) and not from a home socket (Mode 1 and 2).

The European Commission should provide regulation for a simplified and accelerated permitting and processing for deployment of charge spots and battery switch stations. Such regulation should provide guidelines to municipalities, regions and Member States to avoid different rules and enable harmonised and quick deployment of infrastructure across the EU.

In the short to medium term a mix of battery in electric vehicles and plug in hybrids will be brought to the market. The main prerequisite to allow and accelerate the mass adoption of these vehicles is to have the charging infrastructure in place.

EU should set mandatory requirements to accelerate the deployment of charging infrastructure by setting targets and removing administrative hurdles. The EU can adopt legislation by setting mandatory targets for in electric vehicle charging infrastructure in each Member State. Such requirements can include:

Overall minimum coverage of (public) charging infrastructure;

Specific quotas of coverage for long distance driving (e.g every 50km);

Limited time procedures and costs for permits and grid connections for charge spots and battery switch stations.

Utilities and DSOs should support the connection of charging equipment by reducing connection fees of charging infrastructure compared to buildings and houses. Such logic should be applied, if charge spot s can be monitored remotely and smart grid functioning applied.

In open access it should be allowed to use the infrastructure of other service providers if a roaming agreement exists or by the use of pre-paid cards. No other special rules should be applied on the service provider at this stage of market penetration. Once in electric vehicles gain higher market volumes more regulation can be considered.

To allow sufficient flexibility for Member States to implement an in electric vehicle infrastructure, it is proposed to have Member States draw up a plan defining how to meet these targets. Member States should clarify how they accelerate the uptake of electric vehicles by putting the infrastructure in place. Examples of measures for a Member State to include in such a plan are:

Make new buildings in electric vehicle-ready, implying to include cabling for charge spots for in electric vehicles

Allow batch applications for permits to install charging infrastructure;

Give the right to install a charge spot in a shared or public parking (similar to the French regulation) as well as in in private households;

Review and simplify metering requirements;

Public procurement of in electric vehicles;

Support schemes for infrastructure such as loan guarantees and direct subsidies.

1.6 The challenge of EV adoption in context of energy systems

The integration of EVs in electric power systems poses new challenges in terms of regulation and business models. New electricity market agents dealing with EV charging and EV aggregation, in charge of developing charging infrastructure and providing charging services are stakeholders that will influence the EV architecture and its energy management. In this context the energy management of the EV has to consider, several charging modes such as EV home charging, public charging on streets, and dedicated charging stations, and ICT-based solutions for optimized recharging interfaces and methods (inductive; continuous; fast). The involved market agents and their commercial relationships are depending on the energy management provided to the end user. New business models for vehicle to grid applications under which the storage capability of EV batteries is used for providing peak power or frequency regulation to support the power system operation will be based on the EV architecture and the energy management capability of the vehicle. The optimization process of energy management will include time of use pricing, smart meter deployment, stable and simple regulation for reselling energy on private property, roll out of public charging infrastructure as well as reviewing of grid codes and operational system procedures for interactions between network operators and vehicle aggregators.

In this context a number of expected impacts are listed below in relation to the topic of advanced system architecture and energy management for electric vehicle.

A number of factors lead to the expectation that battery costs will decline over time. Automotive grade Lithium batteries have no meaningful global sales at this time. Increased volumes typically introduce manufacturing or scale efficiencies and encourage new manufacturers to enter the market, increasing competition and reducing prices. Novel enhanced control algorithms are expected, which will improve efficiency and enable downsizing as more is learned about battery wear mechanisms from field experience. Electrical energy required for cabin heating and cooling directly reduces EV range, so weather conditions become relevant. Efficiency improvements in electrically driven EV heating and air conditioning systems and cabin insulation to further reduce demands on the battery it is expected together with increased energy recapture through advances in regenerative braking through innovations like ultracapacitor/battery combinations. EV batteries have substantial potential for cost reductions as production volumes increase perhaps to €115/kWh with large volumes. The overall incremental price of a EV driven by the battery cost is likely to decline from a combination of lower battery prices and an ability to use smaller batteries while maintaining range and other capabilities through design innovations.

1.6.1 Smart grid integration of EVs

Energy sources including wind, solar, nuclear, and hydro create little or no emissions (though their construction and maintenance certainly imply some embodied energy. The technology exists today to make grid generation emissions-free by substantially raise electricity prices and the issue is economic deployment of zero/low emitting generation resources. Given that the grid has no energy storage, to maintain system stability grid operators must tune total output to precisely match real time loads, every moment during every day. The unique nature of EV charging offers the new opportunity for grid operators to tune the charging load to match intermittent renewable generation sources such as wind and solar. EV owners are not interested about the precise power charging levels of their vehicles at any particular time, since they are interested that the vehicle is charged sufficiently by the time of their next departure. This has an important effect on the use of vehicle-based energy harvesting and the management of combinations of different energy sources and storage as well as the management and optimization of energy storage ageing, charge monitoring and certification of energy content.

1.7 EV Roaming from a service provider perspective

During the Green eMotion project contributed to the specifications in WP3 and later realized the roaming interfaces based on Green eMotion interfaces. These roaming specifications are referred to in Report 1 and the WP3 reports. Aside of Green eMotion, Better Place worked intensely to develop the concept of EV roaming, which is explained below. Parts of the information is what Better Place brought to the project on roaming and was later aligned to fit the requirements of Green eMotion roaming specifications in order to demonstrate end to end roaming in Green eMotion.

Better Place EV Roaming Concept

As with mobile, ATM, or road-toll roaming, electric car roaming enables the seamless transition of subscriber services between multiple networks. In the electric car arena, electric car operators and charge network operators facilitate electric car roaming. Electric car operators enable subscribers to connect to charge spots (CSs) and receive charging services using their credentials. Charge network operators enable electric car operator subscribers to connect to their charging networks and receive charging services using their electric car operator credentials. Electric car roaming is essential for providing efficient and effective charging services to subscribers across cities, countries, and charge network operators. The Better Place roaming solution is currently available for global deployment.

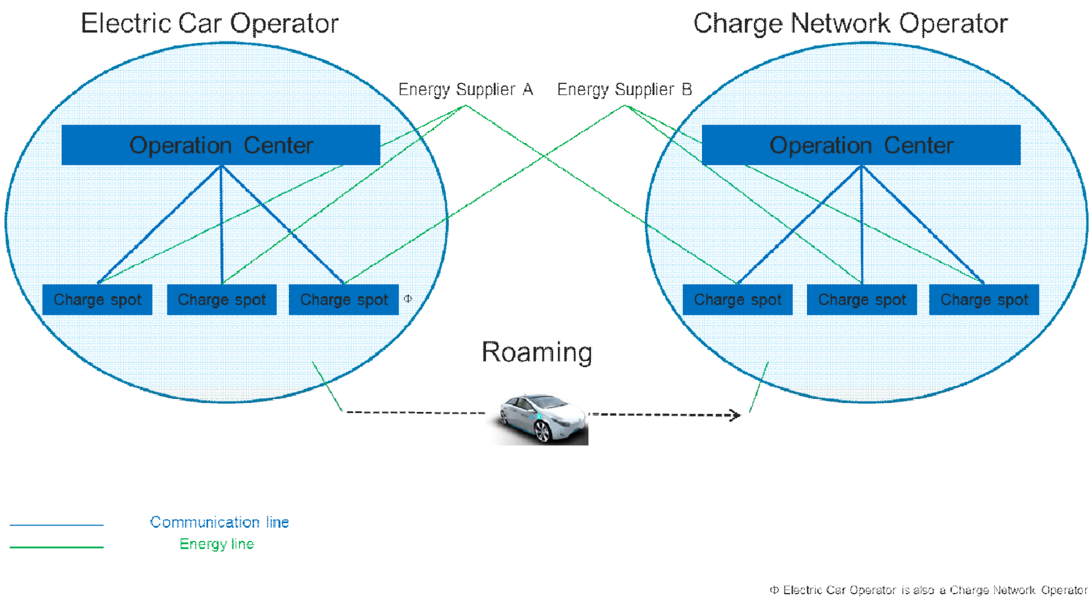


Figure 1: Electric Car Operator Roaming Agreements

Roaming is defined as the seamless transition of subscriber services between multiple networks while still being billed by the original subscriber's network. In wireless telecommunications, roaming ensures that a wireless device:

- Remains connected to a wireless network.
- Never loses the connection.
- Receives its registered services through the local network.
- Pays for services using its service provider credentials.

In other words, roaming extends a device's connectivity service to a different location from where the service is registered.

Traditional GSM roaming is defined as the ability for a cellular customer to automatically make and receive voice calls, send and receive data, or access other services to which the user is enrolled with his/her home service provider when travelling outside the geographical coverage area of the home network, by using a visited network. The services are subject to a roaming agreement between the cellular carrier partners.

For example, a customer may not be able to send or receive SMS text messages (only phone calls) if this was not agreed upon between the cellular carrier partners.

Roaming can be achieved by using a communication terminal or the subscriber's identity in the visited network. Roaming is technically supported by mobility management, authentication, authorization, service policy control, and billing procedures.

> Mobile roaming is using your mobile phone on another mobile operator, while still being billed by your home mobile operator.
>
> Your mobile phone number and potentially all your other services remains the same while roaming.
>
> When roaming on another (visited) network, that network's mobile operator bills your existing (home) mobile operator for calls (or services) you make while using services on their network.

A roaming agreement between the visited network and the home network enables a subscriber to connect to a visited network. The roaming business aspects are negotiated between the roaming partners in roaming agreements, including how the billing of services obtained in the roaming operators is determined. Legal aspects associated with authentication, authorization, and billing of visiting subscribers is also determined in roaming agreements.

In general, the mobile roaming process includes the following stages:

1. A mobile device is turned on or transferred via a handover to a new network. This represents the physical connection of the device to the new network. This is performed by the GSM in cellular roaming, ATM (bank) card in ATM roaming, and the membership (RFID) card and cable in Better Place electric car roaming.
2. The new, or visited, network identifies the subscriber. In Better Place electric car roaming, this corresponds to identifying the Better Place membership (RFID) card.

3. The new, or visited, network checks if the subscriber is registered with its own network. In Better Place electric car roaming, this corresponds to authenticating the Better Place membership (RFID) card and authorizing the subscriber credentials.
4. In case subscriber is not registered with its own network, the new, or visited, network attempts to identify the subscriber's credentials (i.e., authentication and authorization) with the subscriber's home network.

   If a roaming agreement between the two networks has not been established, the service may be denied by the visited network or the visited network may seek approval through a clearinghouse service. In Better Place electric car roaming, this corresponds to the authorization process.

5. The visited network contacts the home network and requests service and policy information.
6. After the home network sends the service and policy information, the visited network creates a temporary subscriber record for the device. The home network also updates its database to indicate that the mobile device is roaming on a visited network so that information sent to that device can be relayed.

The service usage by a subscriber in a visited network is recorded in a Transferred Account Procedure (TAP) file for GSM and is sent to the home network for billing. The home network operator then bills these calls to its subscriber with an optional mark-up or local tax.

1.7.1 Better Place Roaming

An electric car driver may have a subscription with an electric car operator that fulfills the subscriber's charging needs using its own charging network or another electric car operator's charging network. The subscriber's electric car may also be plugged into a CS operated by a charge network operator that is not an electric car operator. While the subscriber may receive charging services from the charge network operator or another electric car operator, the subscriber's business interactions are solely with the original (home) electric car operator. Therefore, only the home electric car operator handles the subscriber's authentication, authorization, charge service policy, and billing.

Better Place roaming involves interactions with three parties:

- The subscriber.

- The electric car operator to which the subscriber subscribes.
- The charge network operator or another (visited) electric car operator.

Note: *The relationship between the electric car operator and the charge network operator may involve additional intermediaries (e.g., a clearing house).*

Electric car roaming is defined as a business practice on top of interoperability. Interoperability in the field of electric cars is defined as the physical capabilities enabling an electric car to access a CS. In other words, interoperability is a prerequisite for roaming.

An electric car is considered roaming when all of the following conditions are met:

- A subscriber connects an electric car to a CS, which is not operated by the subscriber's electric car operator (i.e., a visited CS).
- A subscriber receives charging services from a visited charge network operator.
- The subscriber pays for charging services only to the subscriber's electric car operator and not to the charge network operator.

A subscriber is defined as a person (or vehicle) with a means of identification issued by an electric car operator (e.g., a Better Place membership card), which uniquely associates that person (or vehicle) with a service contract with that operator. A subscriber may be associated with one or more electric car operators thus have multiple membership cards.

In the electric car arena, the following types of operators may facilitate roaming:

- **Electric car operator** – Enables subscribers to connect to CSs and receive charging services using the subscribers' credentials.
- **Charge network operator** – Enables electric car operator subscribers to connect to its charging network and receive charging services using the subscribers' credentials with its electric car operator.

The roaming business processes should be considered from the perspectives of both types of operators.

In order to support electric car roaming, both types of operators should establish and adhere to the following basic rules:

- The electric car operator must establish a roaming agreement directly with a charge network operator or indirectly though a clearinghouse.
- The charge network operator and electric car must comply with the following standards:
    - Electric car conductive charge system (i.e., CS) standards: IEC 61851-1.
    - Plugs, sockets, socket-outlets and vehicle couplers (i.e., connector) standards: IEC 62196-2.
- The electric car operator (as the membership card provider) and the charge network operator must comply with membership card standards (i.e., RFID).
- The charge network operator is expected to share its charging network availability with the electric car operator in order to provide better service to the electric car operator's subscribers (i.e., by directing subscribers to all suitable CSs).

1.7.2 Electric Car-CS Interactions

The following diagram broadly outlines the data exchange concept between the electric car operator and the charge network operator. The diagram describes the high level, fundamental data exchange.

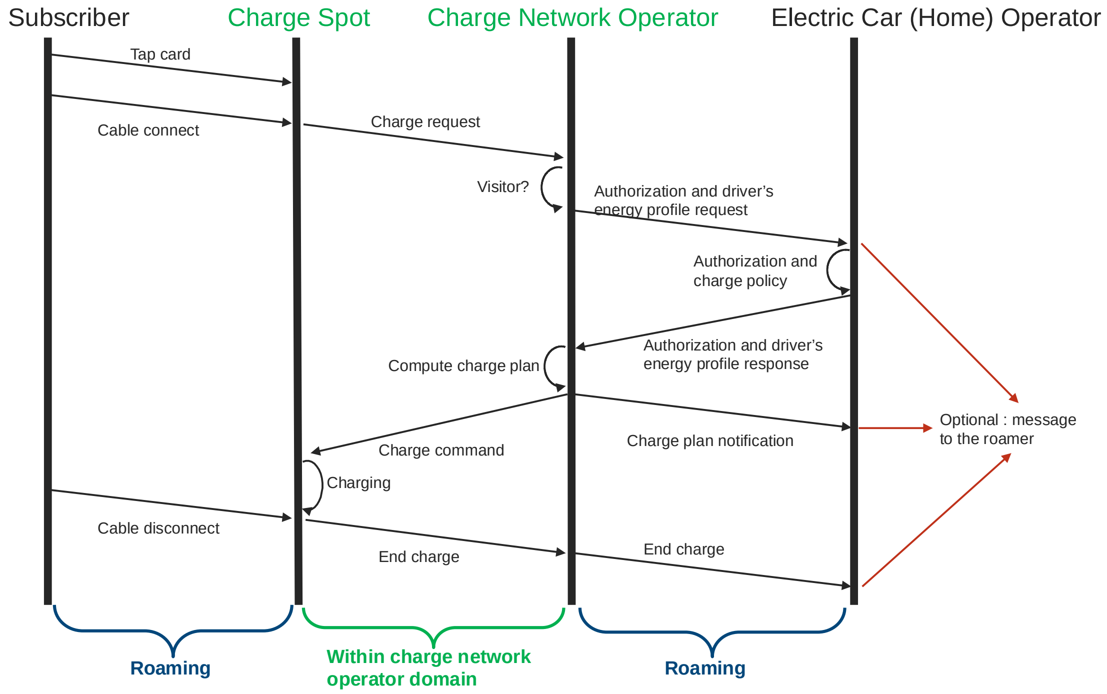


Figure 2: Conceptual Roaming Message Flow

- **Authorization and Energy Policy Request /Response** – The charge network operator authorizes the subscriber (roamer) with the subscriber's electric car operator and receives the subscriber's energy policy.
- **Energy Entitlement Notification** – After calculating the subscriber's energy entitlement and expected delivery time, the charge network operator sends this information to the electric car operator.
- **While Charging** – While charging, the charge network operator sends information to the electric car operator.
- **End of Electric Car-CS Transaction** – At the end of the electric car-CS transaction, the charge network operator sends information about the supplied charging service to the electric car operator.
- **End of Electric Car-CS Session** – The charge network operator informs the electric car operator of the reason for the termination of the electric car-CS session (e.g., cable disconnection, CS malfunction, CS inactivity, etc.).

1.7.3 Business Requirements

An electric car operator can establish roaming agreements with a charge network operator through the following channels:

- Bidirectional / direct roaming agreement between operators.
- Through a third party clearing house.

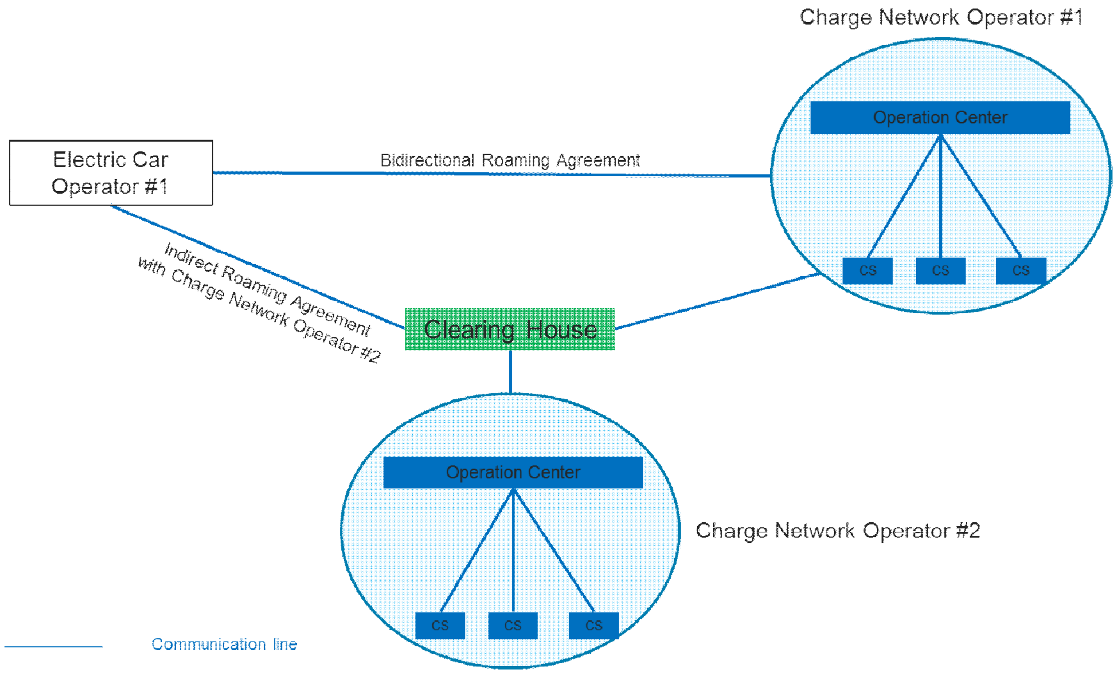


Figure 3: Electric Car Operator Roaming Agreements

Charge network operators can offer the electric car operator different charging services based on a variety of business priority policies and service prices. Upon the connection of an electric car to a CS, the charge network operator may publish its energy availability and price scheme to the electric car operator, which then sends a request for service.

The charge network operator and the electric car operator may also establish price agreements or schemes in advance (e.g., how much money the electric car operator pays the charge network operator for a kWh at a specific time). If such a pricing agreement or scheme is not established in advance, the charge network operator can publish its prices each time an electric car connects to a CS or only once, through a clearinghouse.

Example	Description	Iron Ration	Residual Ration	Re-Authorize on Tariff Change?
VIP	Charge as much as possible, as soon as possible, at max power rate, at any tariff.	Unlimited Energy	'0'	No
Best Effort	Charge as best effort.	'0'	Unlimited energy	No
Iron ration and tariff limit	Charge a minimum of 5kWh as soon as possible, at any tariff, at max power rate. Following that, Charge only when tariff is below $0.02 per kWh.	5KWh	Unlimited energy Tariff limit: $0.02/kWh	No
Iron ration and best effort	Charge a minimum of 10kWh as soon as possible, at any tariff, at max power rate. Following that, Charge as best effort.	10KWh	Unlimited energy	No
Iron ration and time limit	Charge a minimum of 3kWh as soon as possible, at any tariff, at max power rate. Following that, Charge 16kWh (e.g. to full) in 8 hours.	3KWh	Full battery in 8h, assuming 16kWh left	No
Pre-paid Plan	Charge no more than $2 worth. (Tariff reported as $0.1/kWh by CNO in the authorization Request)	'0'	20 kWh Tariff limit: $0.1/kWh	Yes

Figure 4: Energy services options

1.7.4 Standardization

Roaming transactions are defined through a set of standards that enable interoperability between electric car operators and charge network operators or intermediary clearinghouses. The main areas of concern are electric car to CS and Operations Center (OC) to OC (also known as Network Operations Center (NOC)).

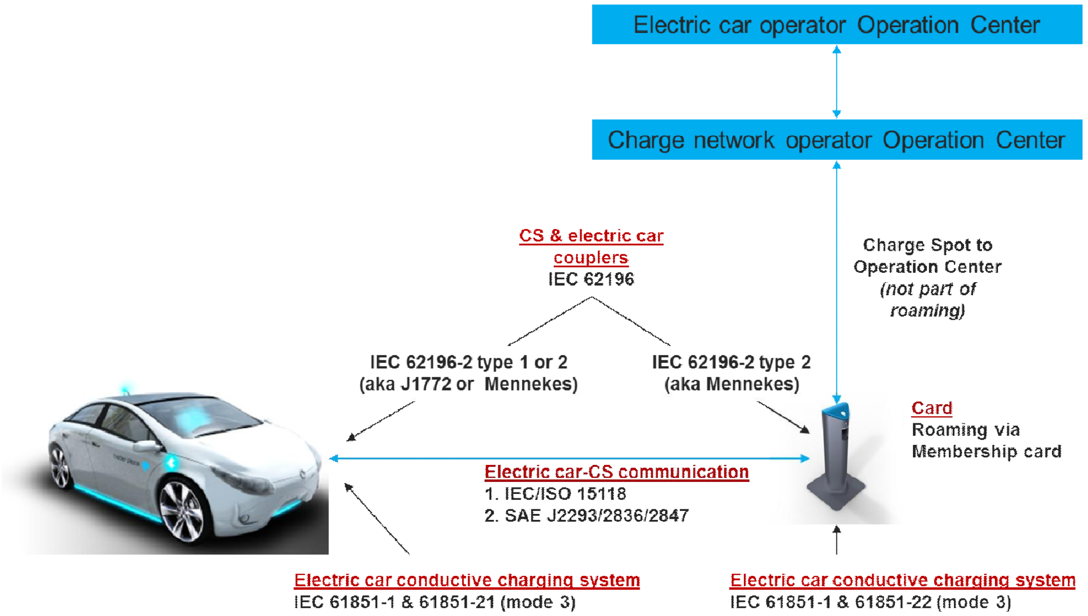


Figure 5: Interoperability and Roaming Standards

A charge network operator is required to enable subscribers to replenish their energy by connecting to its CS network with standard connectors and low-level charging protocols that adhere to the IEC 61851-1, IEC 62196-2, and the CHAdeMO (optional) standards.

A charge network operator is expected to support authentication and authorization services using one or both of the following methods:

- **Membership card** – The membership card utilizes Radio Frequency Identification (RFID). Note that the upcoming electric car-CS digital communication standard (IEC/ISO 15118) may replace the membership card as a means for conveying the subscriber ID (also known as contract ID).
- **Out-of-band authentication and authorization** – Initiated through the subscriber interaction with the charge network operator's Customer Care center. For this purpose, the charge network operator is expected to provide a visible means of identification for the subscriber that provides the following information:
  - The charge network operator's Customer Care phone numbers.
  - The CS and connection port IDs, in a manner that enables the charge network operator to identify the particular CS and port upon request, out-of-band, in order to render service through them.

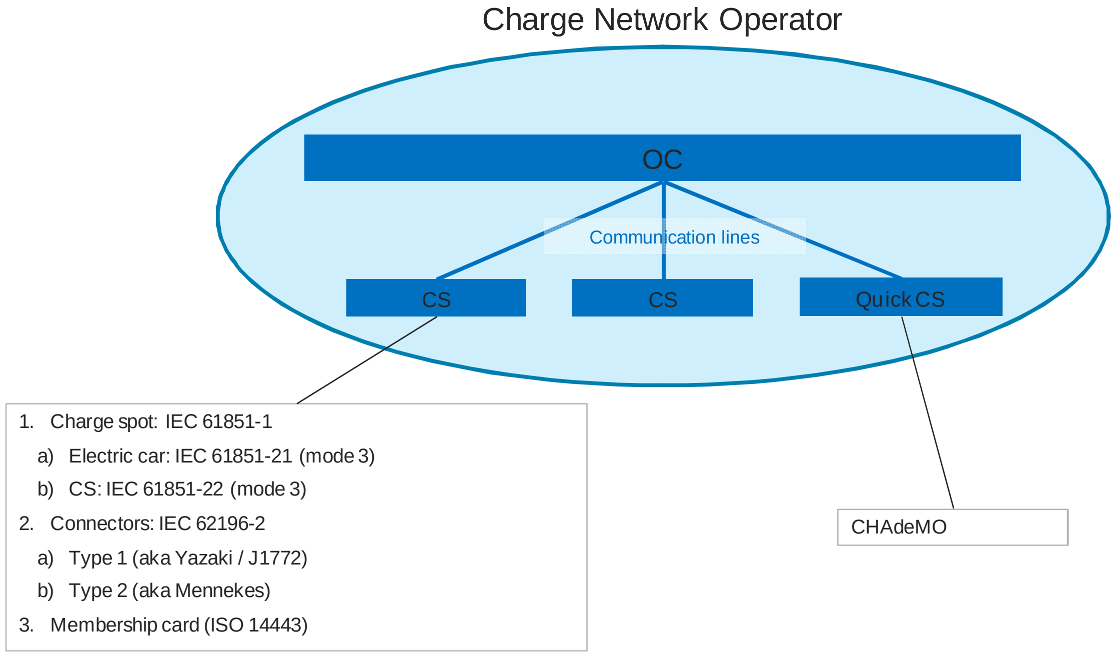


Figure 6: Charge Network Operators Physical Access Standards

1.7.5 Communication

The electric car operator is required to establish a communication channel with a charge network operator, either directly or through a clearinghouse, and exchange a subscriber's information in order to facilitate roaming.

The communication channel is expected to be secure. It should provide mutual authentication of both parties and privacy, via encryption.

1.7.6 Functional Description

Figure 7 provides a functional description of the architecture and various interfaces that facilitate roaming between the electric car and charge network operators. The figure does not define the entire set of functions an operator may provide, but only describes the functions that relate to roaming.

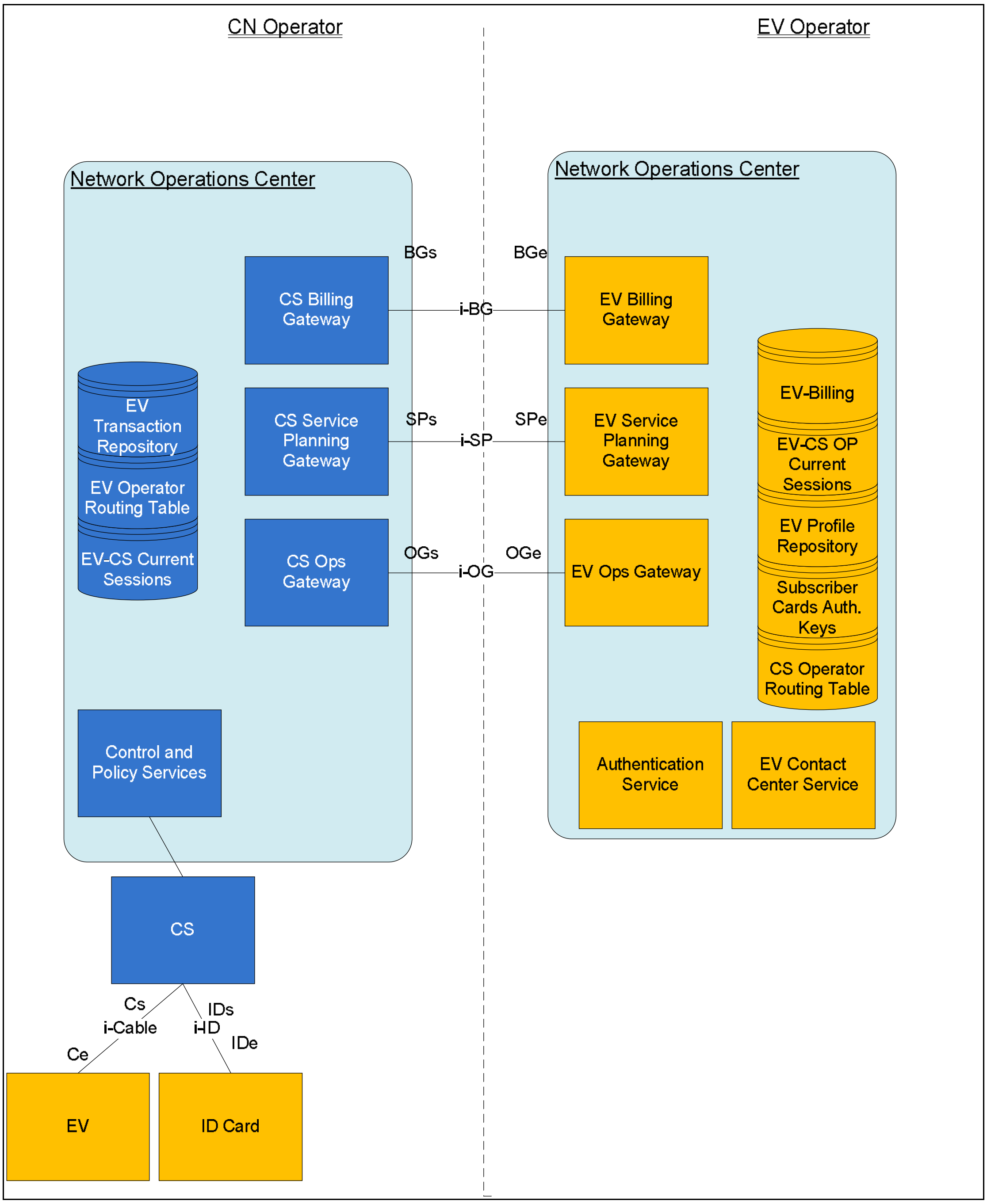


Figure 7: Functional Description – Electric Car and Charge Network Operators

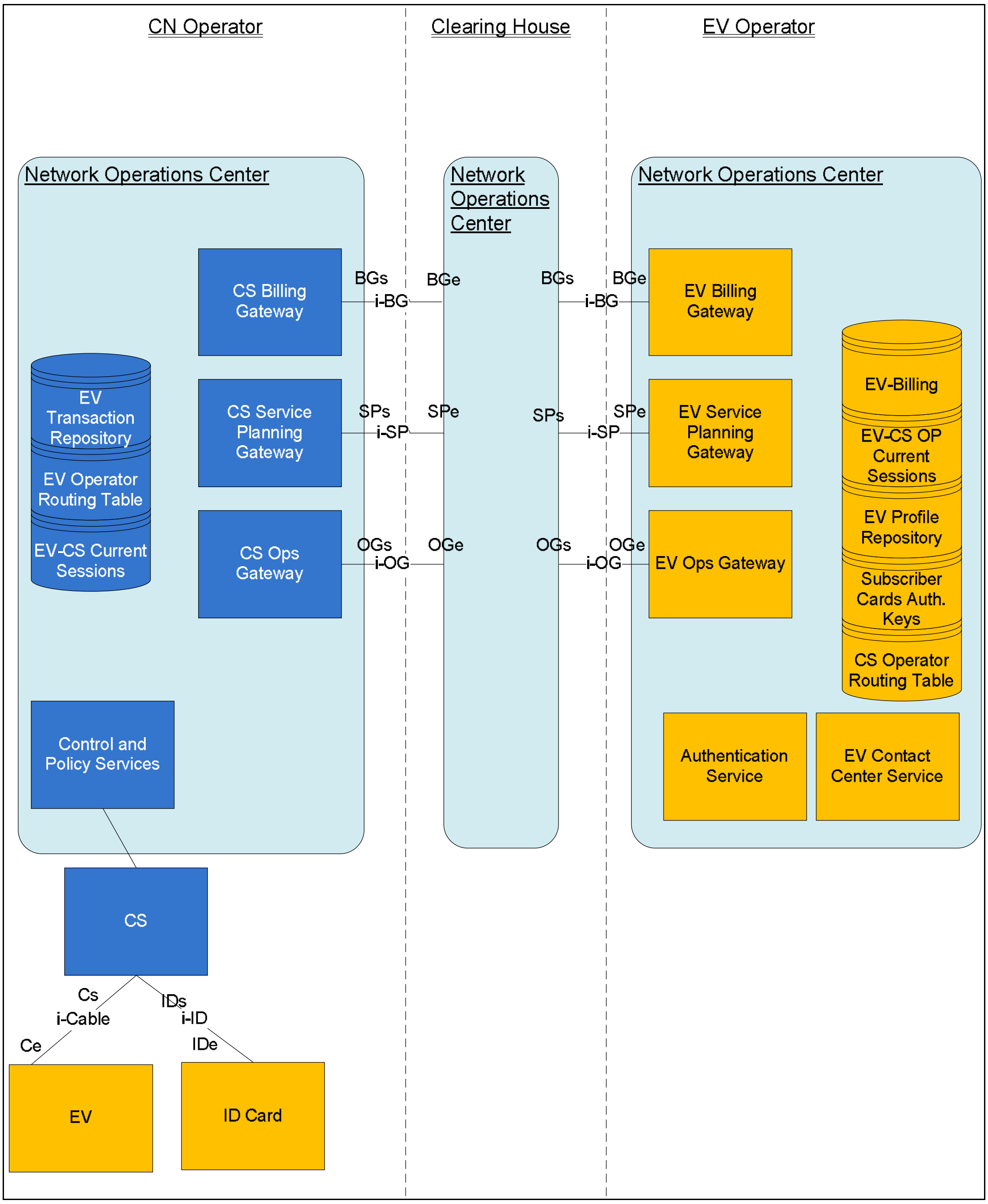


Figure 8: Functional Description – Electric Car and Charge Network Operators via Clearing House

Note:

> ***Figure 7*** *and figure 8 renders functions as separate elements for illustration purposes only. Mapping functions to software/hardware elements is determined by operators.*

Figure 7 includes the following elements:

- Electric car and ID card operated by a subscriber – A customer of the electric car operator.

Note: *The ID card may be replaced by an identification system that, for example, could be the electric car itself.*

- A charge network operator providing energy to the electric car through the i-Cable interface as well as a means of identification and authorization of the subscriber through the i-ID interface.
- A charge network operator's OC in communication with both the CS and the electric car operator, either directly or through an intermediary broker (i.e., clearing house). For more information, see
- *Charge Network Operator's* OC on page 29.
- An electric car operator OC in communication with the charge network operator and possibly with the electric car and the subscriber (i.e., through a Customer Care center, phone, portal, etc.). For more information, see
- *Electric Car Operator's* OC on page 30.

Charge Network Operator's OC

The charge network operator's OC includes the following elements:

- **CS Ops gateway** – The CS operations (Ops) gateway provides authentication, authorization, and policy control interconnect services between the CS and the electric car operators, implementing the i-OG interface's OGs side:
  - The CS Ops gateway routes electric car session initiation and termination requests to the appropriate electric car operator or intermediary using the electric car operator routing table and the electric car operator ID. Session initiation (i.e., a request for service) may result from the control and policy services from the ID card (which is later replaced with the contract ID, via the cable) or the out-of-band request (i.e., the subscriber calls the charge network operator's Customer Care service and provides his/her credentials and card ID).

  - The CS Ops gateway routes authentication, authorization, and policy information for a given subscriber from the electric car operator to its control and policy servers. In addition, the CS Ops gateway provides the electric car operator with frequent electric car-related data (e.g., SOC (if known), energy delivered to the electric car, etc.).
- **CS service planning gateway** – This gateway sends information on CS service availability in charging areas or regions to the electric car operator and receives predicted electric car load per charging region information from the electric car operator.
- **CS billing gateway** – This gateway compiles and sends billing requests (in the TAP3 protocol) to electric car operators using the electric car transactions repository. The CS billing gateway implements the BGs side of the i-BG interface.

Electric Car Operator's OC

The charge network operator's OC includes the following elements:

- **Electric car Ops gateway** – This gateway is responsible for facilitating authentication, authorization, and policy control for electric car sessions created by the charge network operator, via interaction with the electric car operator services. It implements the OGe side of the i-OG interface. The gateway forwards authentication and authorization requests (that are part of session initiation requests received from the CS Ops gateway) to the authentication and authorization service and provides results to the charge network operator. If authentication and authorization succeeds, the gateway retrieves policy information from the subscriber profile repository and sends this information, together with the result, to the charge network operator. The electric car Ops gateway can initiate a change in the policy for an electric car session that is currently up, sending the change request to the CS Ops gateway. The electric car Ops gateway keeps track of current electric car-CS sessions in the electric car-CS session's repository.
- **Electric car billing gateway** – This gateway receives billing information from the charge network operator via the i-BG interface employing the TAP3 protocol. The

gateway updates the billing records for the electric car subscriber in the electric car-billing repository.

1.7.7 Interfaces

- **i-Cable** – This interface provides power to the electric car in a controlled manner, using the following standards:
  - **CS (electric car conductive charging system)** – IEC 61851-1:
    - **Electric car** – IEC 61851-21 (mode 3).
    - **CS** – IEC 61851-22 (mode 3).
  - **Connectors** – IEC 62196-2:
    - Type 1 (aka Yazaki / J1772).
    - Type 2 (aka Mennekes).
  - **Quick charge** – CHAdeMO.

  In future implementations, based on the upcoming ISO/IEC 15118 digital communication standards, i-Cable may also include the i-ID identification function (i.e., contract-ID). In addition, the i-Cable interface may accommodate the futuristic inductive charging.

- **i-ID** – This interface provides a means of authenticating and authorizing a subscriber using a membership card. A challenge/response scheme is used, where the CS challenges the membership card, which computes a response. The subscriber's ID read from the card, the challenge, and the response are then forwarded to the charge network OC (and then to the electric car operator OC) for authentication and authorization.

The i-ID interface is designed to accommodate the following business requirements:

- Following a well-known RFID exchange standard like electronic payment.
- No subscriber information (e.g. secret) should be stored in the CS.
- Better Place private keys (e.g. secrets) should not be stored in the CS.
- Cost effectiveness of the Better Place membership (RFID) card and reader.
- Better Place membership (RFID) card and CS transactions should be less than 100 ms.
- Centralized key and credential management.
- Better Place membership (RFID) card privacy.
- Better Place membership (RFID) card authentication.
- CS authentication is not required.
- Protection against replay attacks.

In future implementations, based on the upcoming EV2Grid ISO/IEC 15118 digital communication standards, the i-ID may be carried over the i-Cable. For more information about the i-ID interface, see *Reader and Card Message Exchange for Better Place Application Transaction* and *Better Place Membership Card Application Specification*.

- **i-OG** – This interface is used for the following functions:
  - Exchange of authentication and authorization information for a subscriber between the charge network operator and the electric car operator.
  - Sending authorization and energy policy profiles for a subscriber from the electric car operator to the charge network operator.
  - The charge network operator may frequently update the electric car operator regarding the charging progress.
  - The electric car operator may frequently update the charge network operator regarding the subscriber's new charge policy and needs.
  - The charge network operator may frequently update the electric car operator regarding the charge offering (e.g., the price scheme).

- **i-SP** – This interface enables the operators to exchange information that enables planning a more efficient service delivery. The charge network operator may provide information on the availability of its CSs (or charging areas/regions). The electric car operator may optimize service to its subscribers by suggesting charging areas with higher availability to the electric car drivers.
  The electric car operator may provide predictions of electric car charging operations in various regions, based on its prediction of electric car traffic and charging patterns.
- **i-BG** – This interface enables a charge network operator to send billing information to an electric car operator in batch operations that may occur several hours or days after the actual energy replenishment transactions. The interface is based on the TAP3 billing file format used in cellular networks and has been extended to support energy services and the membership card subscriber identification scheme.
  Decoupling of the billing operation from the operational flow enables a commercial agreement between the charge network operator and electric car operator, whereby the charge network operator can provide energy to the electric car operator's subscribers even if there is a malfunction in the operational flow. In this scenario, the charge network operator can still present the electric car operator with a bill (which the electric car operator may verify through other means, e.g., investigating the logs of the electric car in question).

1.7.8 Trust and Auditing

In cellular roaming, a visited operator can request that authentication with the home authentication center will be performed whenever a home subscriber attempts a billable operation while roaming. However, presently, this is not supported in Better Place roaming due to the authentication means being a card that is present only at the initiation of the electric car-CS session. The card may or may not be present when attempting to disconnect an operation (in most cases, the card will not be present). Therefore, the electric car operator has no immediate means to accurately verify the billing request by the charge network operator and is required to trust the charge network operator to some extent.

In order to verify that billing is indeed accurate, the electric car operator can perform audits of the electric car's onboard systems and compare these results to the charge network operator's bill.

1.7.9 Roaming summary

- Facilitates mass adoption of electric cars as subscribers are free to driver anywhere, anytime – Mobility freedom is achieved.
- Easy to use solution from the subscriber's point-of-view.
- Follows the industry's well-known, working and popular, cellular roaming standard.

As with mobile, ATM or road-tool roaming, electric car roaming enables the seamless transition of subscriber services between multiple networks. This process enables the mass deployment of electric cars. Electric car roaming is essential for providing efficient and effective charging services to subscribers across cities, countries, and charge network operators.

By utilizing and developing industry-standard, state-of-the-art technology, Better Place has developed an electric car roaming program that is currently ready for global implementation.

2. The Better Place Battery Switch Concept

The national Danish network of 18 Battery Switch Stations (BSS) and approximately 400 charge spots (CS) was deployed 2010-2012. The network provided a solid foundation for gathering consumer data, testing real life experiences of EV driving and analyzing the market oriented approach. More than 2M eKM were logged through the Better Place Network Operations Centre and more than 20.000 switches were performed on the network of BSS.

Alongside, the Netherlands Taxi project demonstrated the capacity of long distance EV driving and the ease with which the batteries are switched. The taxi project, which was located at Schiphol/Amsterdam, served 10 electric vehicles taxis that all had the ability to switch the battery at the station in Schiphol airport.

Below is a table which summarize the data for The Netherlands taxi project, demonstrated as part of the first TEN-T e-mobility Action:

Month	November				December				January					TOTAL
Week	45	46	47	48	49	50	51	52	1	2	3	4	5	21
Days of operation	5	6	6	6	6	6	5	3	4	6	6	6	4	106
Taxis in operation	10	10	10	9	9	8	9	9	9	9	8	8	9	10
Number of switches	182	218	219	188	222	184	152	59	100	163	191	156	154	3,248
Max number of switches/day	45	48	50	42	53	39	44	27	30	44	39	36	45	53
Total distance driven	14,726	16,097	15,592	13,043	13,934	12,256	9,812	4,543	7,211	11,065	11,112	9,138	11,044	237,220
Number of trips (ca.)	380	505	399	300	271	180	181	142	240	331	282	181	338	6,274
Max km's by one taxi/week	2,122	2,151	2,247	2,183	2,416	2,377	1,514	640	1,426	2,034	2,282	2,055	1,908	2,416
Max km's by one taxi/day	565	523	513	545	501	567	454	399	439	510	479	486	592	592

In 21 months the Amsterdam Taxi Project achieved to 237,220 km and 3.248 switches at the station. The maximum km range per week is of 2.412 km per car. In a year the average km per car would be approximately 80.000 km per car.

This best practice case shows the possibilities for the battery switch technology, and its ability to provide a full battery in only 5 minutes, enabling convenient transportation similar to ICE Vehicles.

The BSS have proven to be reliable in fluctuating weather circumstances, and additional charging solutions, such as fast chargers have already been deployed in selected countries. In addition, the fact that several OEM car manufacturers have produced or are planning electric car models, evidences the matured state, which EV driving has reached.

2.1 The battery switch processes

The car is being detected via WIFI and the car enters the switch lane as the door opens

The robot takes over the switch procedure by turning off the car,

The car is being dragged to the swapping spot,

The battery gets switch:

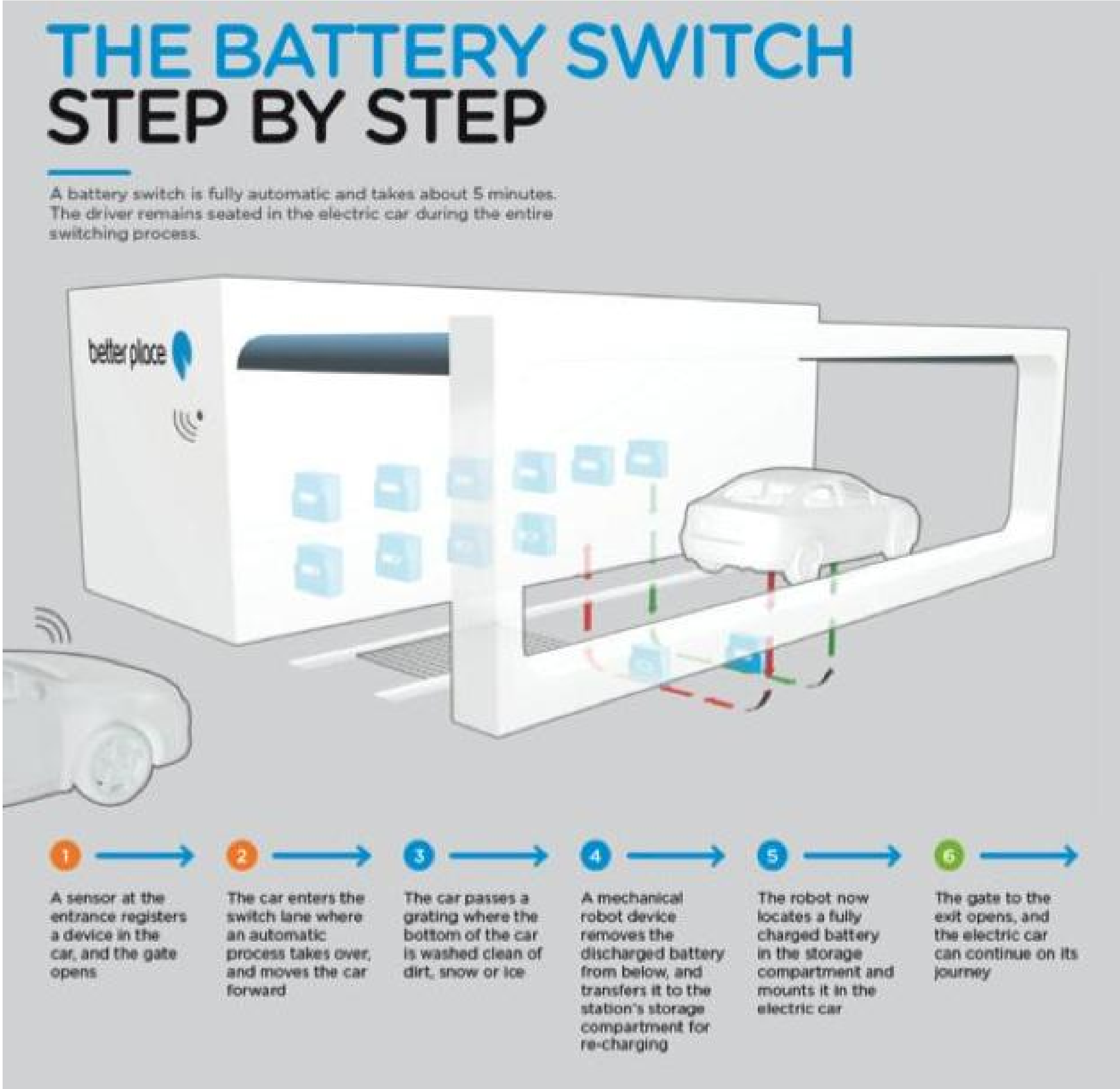
Charged batteries will be moved to a free position in the rack, Uncharged batteries will be put in queue waiting to be charged, if no free charger is available

Defect batteries ready to be picked up for repair. If by any mishap a battery is deemed defect, the battery needs to be stored until it can be picked up for repair.

The car is turned on

The door opens and the driver can continue the ride.

Below is an illustration of the entire process:



During all processes the on-board computer informs the driver:

2.1.1 Connection & charging

Intelligence ensures minimum power consumption based on demand and supply; the ability to control charging makes it possible to charge with as low as 6 kW up to 50 kW.

Batteries are usually charged with up to 35kw. Depending on the demand normal charge will be carried out with 16 to 32 kW, giving a fully discharged battery a full charge at approximately 11⁄2 hour. If demand requires it, a fast charge can be done with 35 kW.

Batteries are fully charged in 40 minutes. When charging with 35 kW, a fully discharged battery can be fully charged in 40 minute.

2.1.2 Battery management & cooling

The Battery Management system is part of the back end systems, and controls parts of the BSS. At all times it is possible to get an overview of what is happening at all stations at the Network Operation Centre.

From the stations it is possible to retrieve information such as State of Charge, State of Health, Delivered Power, Charged Power, Driven kilometers, Cell status and much more.

Via the Battery Management System it is possible to plan logistics actions, forecast and other relevant plans.

The system protects the batteries and extends lifetime.

2.2 The Better Place Service Provider Model

In short to briefly describe the Better Place EV Service Provider Model - it is all about making it easy for the subscriber to drive and to use the infrastructure needed. In reality it is a very complex system that has to work seamlessly in order to support the subscriber at all times.
There are several key components in the EV service provider model that needs to be run as one machine. These components are:

Network Operation Centre (NOC) 24/7 services – available for all subscribers and the key of the solution,

AC and DC stations – available for all subscribers (private, public and semi-public),

Battery Switch Stations – available for switch subscribers, On-board and mobile services.

The figure below provides an overview of the Better Place network of charge spot (CS) sites and BSS. The pictures shows a scenario in which goes a subscriber for a meeting, driving from one part of Denmark to another part using home charging, mobile App, battery switch, on-board system and public charging at the final meeting point.

Subscribers with Better Place in Denmark can use all the publicly available AC charging infrastructure of the network, both of Better Place in Denmark and by the Open Access infrastructure of other EV Service Providers, such as Clever and Clean charge. From home the subscriber can charge using priorities charging (now and here) or you can set-up preferred charging time to minimize peak hour load and to get more renewable energy to charge the car. Furthermore the user can pre-heat the car before driving when temperatures are cold outside, to reduce the battery consumption for the ride.

The figure below shows from left: the public charging station, private charging station, public wall mounted charging station with or without cables and an extender box. All five charging stations are with RFID identification and with mobile or fixed network connection to the Better Place NOC.

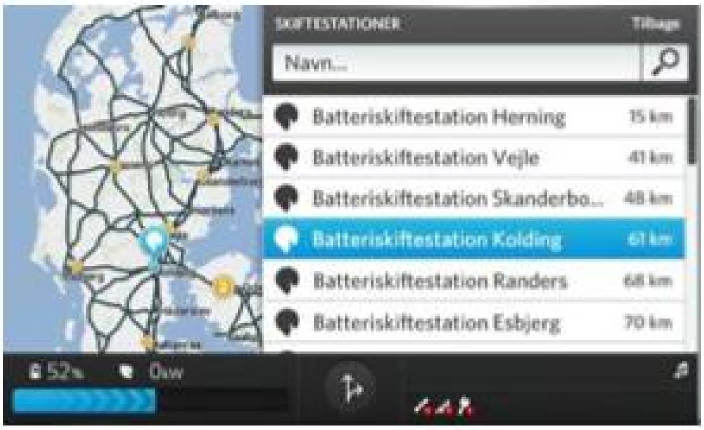
Mobile & on-board services are to be used before and during the drive. From home towards the meeting point in Odense – a 252 km ride – the subscriber can see where to charge and how, and thereby plan when to go and when arrive. During the ride the driver can get full information from the car how on the distance to the next charging location and how much charging it will take to reach the final destination. The on-board system tells the driver at which BSS he or she should stop, and will be guided via the same device to the stations needed. Unlimited switches are part of the standard subscription.

At the meeting point the driver can then charge the car at a nearby located public CS, where the car can charge before the driver picks it up again to return home.

Unlimited AC charging is also part of the standard subscription.

All the activities are being monitored by the Network Operation Centre, which the driver can call for free from his or her phone or from the car if help is needed or if questions occur. This service is part of the standard subscription and is open 24/7.

The figure below shows a screen-shot from the EV in-car telematics system.



The foregoing information evidences the maturity of the EV concept, including the availability of an already existing infrastructure in Denmark, the availability of information from studies on consumer usage and satisfaction, and the enactment of Pan European standardized infrastructure.

3. The Better Place Business Model

Shai Agassi founded better Place in 2007. The company was focused around operations of charging networks for EVs mainly in Denmark and Israel but also operated smaller local networks in Australia, USA and Holland.

The company's core business model was focused on operating networks that could extend the range of a normal EV. The objective was to enable any driver to travel freely and provide a functional alternative to ICE vehicles. The central technology behind this was to operate battery switch stations (specified in D5.1) that were installed on major transport hubs around Denmark and Israel. The basic understanding of the use pattern of drivers was that home charging from a regular home charging station should function as the main source of electricity for the driver, as a fully charged battery would cover up to 90% of any driver's needs in these two countries. The battery switch stations would enable drivers travelling beyond the range of a fully charged battery to switch an almost empty battery with a fully charged battery, thus, allowing the driver to travel an unlimited amount of kilometers. Better Place's ambitious vision was to make EVs a mass-market product.

3.1 Subscription-based

To support this type of network and use pattern, Better Place chose a business model that would separate the ownership of the battery from the car, meaning that the customer of a battery switchable car would own the car but not the battery. The battery would be the ownership of Better Place. Better Place packaged the lease of the battery together with electricity corresponding to the customer's kilometer usage, deployment of a home charging station, access to a nation-wide network of public charging stations and battery switch stations and various ICT services delivered to the customer on web, mobile and OSCAR, a telemetric system developed and operated by Better Place.

Pictures of the Better Place developed telemetric system OSCAR. The system provided the driver with information about routing, SoC and charge spots and battery switch stations. Also, it was possible to access Better Place 24-7 customer care via the system.

The Better Place subscription model was very much similar to what mobile operators offer their customers. A customer would sign up to the number of kilometers matching the expected yearly usage. The subscription model was designed to offer the customer security, both in terms of risk of the battery value and in terms of providing the customer with *only on bill* - no unexpected costs.

A Better Place customer could choose between 6 different kilometer packages:

KM PER YEAR	UP TO 10,000	UP TO 15,000	UP TO 20,000	UP TO 30,000	OVER 40,000
MONTHLY FEE	DKK 1,495	DKK 1,695	DKK 1,895	DKK 2,495	DKK 2,995
EXCESS KM[1)]	DKK 2.24	DKK 1.70	DKK 1.42	DKK 1.25	-
	(minimum price for 12 mths: DKK 27,935)	(minimum price for 12 mths: DKK 30,335)	(minimum price for 12 mths: DKK 32,735)	(minimum price for 12 mths: DKK 39,935)	(minimum price for 12 mths: DKK 45,935)

Customers were charged an up-front fee combined with a monthly payment. Similar to mobile subscription, a Better Place customer also signed a contract with a minimum period. The length of this period corresponded to national laws on this matter.

3.1.1 Battery-switch customers

The majority of customers were expected to choose a subscription supporting a car model with battery-switch enabling technology. Therefore, this type of subscription was the key focus in sales and marketing as well as development. However, Better Place never managed to engage more than one car model, a Renault Fluence ZE, in this program. This circumstance resulted in unfulfilled sales targets and slowly pushed the focus of the business model - at least in the case of Denmark - towards selling, marketing and developing solutions for fixed-battery car customers.

The Renault Fluence ZE with switchable battery

3.1.2 Fixed-battery customers

In Denmark, Better Place offered similar subscriptions to car owners of fixed-battery EVs. Especially, fleet customers from the public sector were more interested in subscriptions of this kind. The core attributes of battery switching were less valuable to customers driving shorter distances and even often driving within boundaries of a municipality. Also, the Renault Fluence ZE was not the optimal car model for a segment that traditionally has been purchasing smaller compact car models. For this segment Better Place offered a similar subscription, but without a battery lease and access to OSCAR (Better Place telemetric system) incorporated in the package.

In the last four months of operations Better Place also offered semi-fast charging (22 kW, AC and DC) on selected locations along the network of battery switch stations.

3.2 Target groups and customers

Better Place's offerings were designed to accommodate almost any type of driver. As mentioned, Better Place Denmark was offering both subscriptions to both owners of battery-switch cars and fixed-battery cars. The target groups were both fleet and private customers.

3.2.1 Private customers

The private customers were expected to be less relevant for the first years of operation as a car purchase for the type of customers is the second-largest investment in a family economy after purchasing a house or apartment. It was expected that the risk of buying an electric vehicle would be too high for the majority of private customers for the first couple of years until the car customers had matured and gotten more comfortable with buying an EV. However, it was also expected that the Better Place could attract some private customers with either a strong environmental agenda, an interest in new technology or a combination of both. In Denmark, the network of battery switch stations only had one year of operation from the opening of the first station to the bankruptcy and only 6 months of operations of a fully nation-wide network of the 18 scheduled stations. Through this period, the mix of private customers with battery switch cars showed to be very diverse in terms of gender, age and geography. The amount of private customers with fixed battery cars was very limited but would have been expected to grow in short-term after the bankruptcy due to the introduction of attractive car models in this segment (Renault Zoe, VW eUp, BMW i3 and Tesla Model S).

3.2.2 Fleet customers

The fleet customers were targeted in two different ways depending on whether they were public or private sector fleet customers. In the years since inauguration of Better Place Denmark, many municipalities and private companies signed strategic partnerships with Better Place declaring an interest in supporting the EV market in the future. The two fleet segments mainly differed in the type of car model to support. Among the private fleet customers the Renault Fluence ZE was the most attractive car model through the entire period of operation. The majority of public fleet customers were municipalities purchasing smaller, compact EV models for home care operations. For this segment fixed-battery car models such as Renault Kangoo ZE, Citroën C-Zero, Peugeot iOn, Mitsubishi iMiev and

Nissan Leaf was the preferred choice. Therefore, the focus in this segment was to deliver competitive solutions for fixed-battery customers.

A Renault Kangoo ZE charging at a Better Place charge spot. A food delivery company that only delivered goods to customers in EVs owned the car.

3.3 The Charging Network

The charging network operated by Better Place in Denmark consisted of various components:

Network operating center: Better Place developed and operated its own network operating center (NOC) communicating with the entire network. The system enabled Better Place to manage each charging session, manage load on a site of multiple charging sessions and communicate with the electricity supplier

Home charging spots: Better Place installed home charging spots for each customer. The charging spot was connected to a Better Place had a variety of solutions depending on the needs of each customers:

Wall mount or post

1-phase of 3-phase

3,3 kW or 11 kW

Choose between two different electricity providers: DONG Energy or VERDO

Public charging stations: Better Place operated a network of publically available charging stations. The charging stations were also communicating with the NOC and were placed on strategic locations, mainly in city centers, malls, transportations hubs etc. Better Place operated approx. 1200 publically available plugs throughout Denmark until bankruptcy. The publically available charging stations could accommodate two types of customers:

Better Place subscribers: The electricity consumed on these charging stations was included in the kilometer-based subscription and could be accessed by using the RFID tag also used to access home charging spots

Non-Better Place subscribers: Any EV-driver could access these charging stations by calling Better Place 24-7 customer service paying over the phone with credit card details. This was a low-tech solution that was planned to develop as the market size would grow and the business potential would arise.

Better Place's network of public charging stations consisted of two types of charging solutions:

AC charging stations with 11 kW output and Mennekes outlets

DC charging stations with 22 kW output and CHAdeMO outlets

A Better Place 22 kW charging station with combined Mennekes/AC and CHAdeMO/DC . In March 2013 8 stations of this kind were installed along selected battery switch stations.

3.3.1 Battery switch stations

Battery switch stations: Better Place's most significant attribute in terms of charging was the network of battery switch stations. Battery switch stations were put in to operation in three regions throughout the world:

Denmark: A nation-wide network with 18 stations operated across the country allowing EV customers to travel across the country in 7 hours. This would take approx. 6 hours in a regular ICE car.

Israel: A nation-wide network of 36 stations operated across the country.

Holland: 1 battery switch station in Amsterdam International Airport Schiphol to support a taxi demonstration project supported by EU under the TEN-T programme.

This figure illustrates the location of the 18 battery switch stations in Denmark. The stations were located along highways and major traffic points. The main purpose of the battery switch stations was to enable drivers to extend range on longer trips. The station with the cross was never realized.

The battery switch system is specified in detail in deliverable 5.1. Below is an outline of the key aspects:

Battery storage

Charged batteries ready to be switched. Charged batteries will be moved to a free position in the rack.

Uncharged batteries ready to be charged. Uncharged batteries will be put in queue waiting to be charged, if no free charger is available.

Tool boxes for different types of batteries; in order to handle more than one battery form factor, it's needed to hold more than one tool box for switching battery.

Defect batteries ready to be picked up for repair. If by any mishap a battery is deemed defect, we need to store the battery, until we can pick it up for repair.

Charging

Intelligence ensures minimum power consumption based on demand and supply; the ability to control charging makes it possible to charge with as low as 6 kW up to 50 kW.

Usually charged with up to 35 kW. Depending on the demand normal charge will be done with 16 to 32 kW, giving a fully discharged battery a full charge at approx. 1½ hour. If demand requires it a fast charge can be done with 35kWA.

Fully charged in 40 minutes. When charging with 35 kW a fully discharged battery can be fully charged in 40 minutes.

Faster charging with 50 kW can be done if needed. Should a demand require faster charging then 40 minutes, it's possible to reduce charging time with 5 to 8 minutes, by applying 50 kW, for short time periods during charge.

Charging of the batteries in the BSS is done in optimal conditions as cooling of the batteries is done simultaneously

Battery management

Managing logistics

Controlling battery status

Panning

Battery cooling

Protects the batteries and extent lifetime – especially if they are hot when charging starts after driving in high ways

Cooling with 5˚C high pressure air when fast charging

Cooling only if battery core temperature exceeds a certain threshold

Battery cleaning before the switch

Batteries will be cleaned before the actual switch. The full switch time from the time the customer/car has been identified in front of the gates, until exit from a completed battery switch is less than 5 minutes.

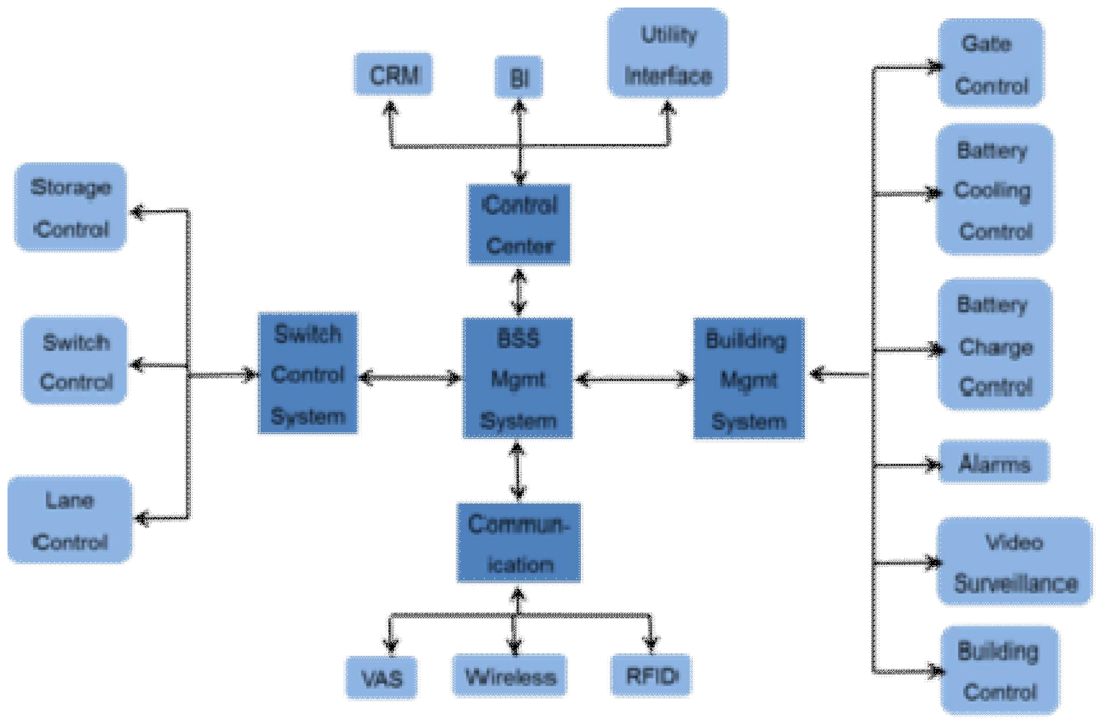
Capacity and planning

1 lane - expandable to 2 or more

Up to 16 batteries per lane - can be further expanded in a modular way if needed

Intelligent planning forecasts demand and determines the needed charge mode

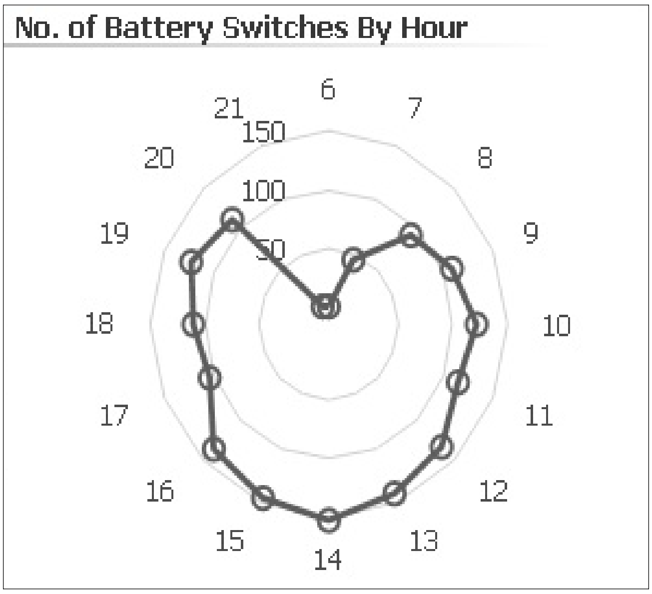
Data analysis determines expected loads and relocation of batteries between stations



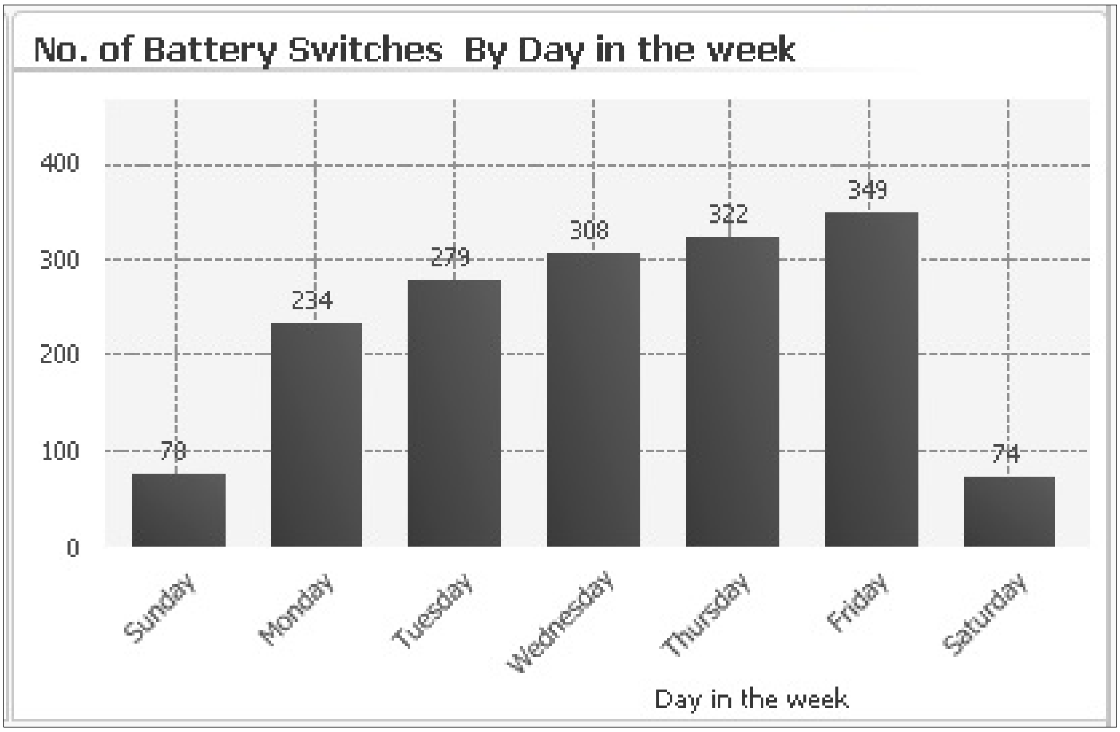
The figure above is a system overview of a battery switch station. The figure is specified in detail in deliverable 5.1.

Since the first costumers started using the BSS for switching their EV batteries for long distance journeys, Better Place has logged the number of switches and the energy consumption via the Network Operation Center.

The most interesting data regarding the switching itself is the ‘time of day overview’ and ‘week overview’. The figures below illustrate the time of day where people switch their batteries. The numbers are accumulated since the opening of the BSS, and therefore represent an accumulation of the charging hour on each day of the first BSS in Denmark., in Gladsaxe, a Copenhagen-suburb from its opening in February 2012 to October 2012.



The figure shows that the vast majority of switches have taken place between 7 AM and 20 PM with only minor changes in the numbers of each hour. Each hour in this interval have had between 50 and 175 switches, which is of course relative to the number of EVs with a switchable battery currently driving on the Danish road network.



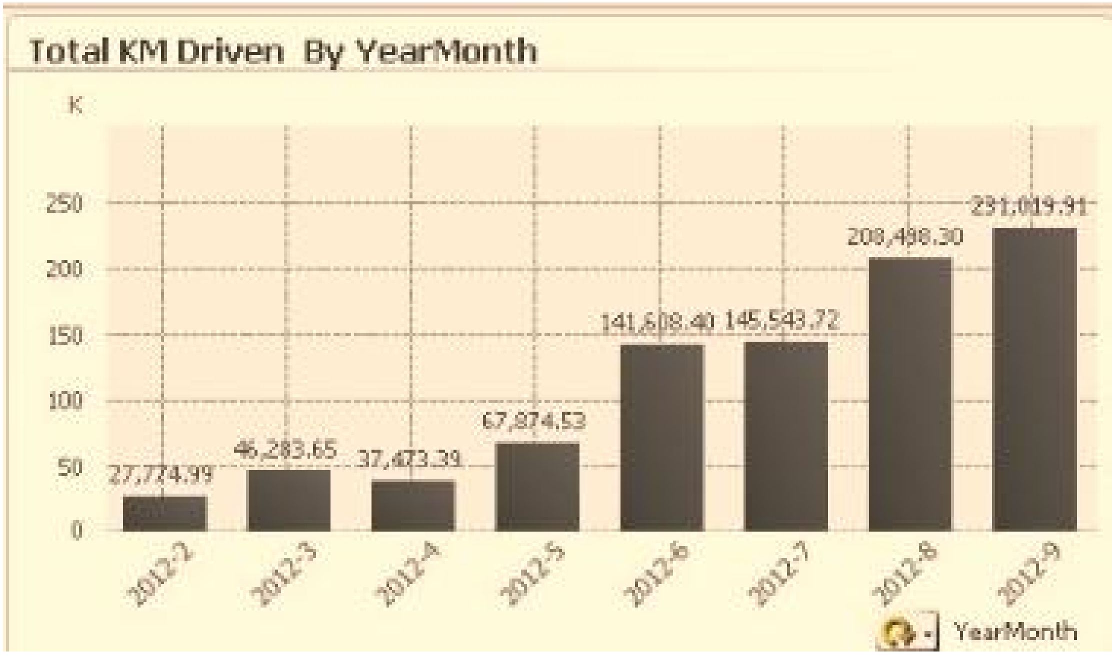
The second interesting data analysis on the switching itself is illustrated in the figure above, which illustrates the number of battery switches at Gladsaxe BSS during the week, with each day accumulated dating back to the opening to the public.

The bars illustrate that the majority of the switches have taken place between Monday and Friday and with only limited switches occurring during the weekends. There can be many reasons for this tendency, but it can be assumed that at this stage the majority of the switches have been carried out on corporate EVs, which primarily are being used during the work week.

When considering the EV customers of Better Place Denmark, analytics show that since February 2012 when the Renault Fluence Z.E. was released on the Danish markets, the following data and results have been retrieved by the Better Place Denmark Network Operation Center (NOC):

1.191.613 e-km driven in electric vehicles
13.519 switches performed in the full Danish BSS network
2.162 switches performed at Gladsaxe BSS

The monthly analytics of the development during these months, up to September 2012, can be seen in the graphics below.



3.3.2 Battery switch standardization efforts

Over the years Better Place has also played a very active role in maturing the technology of battery switching through involvement in the PT3 batteries working group appointed by the European Standards Organizations. The group was among other things asked:

To propose, if needed, additional standards or regulations for the efficient and safe usage of fixed and **removable battery systems** for EVs during their life cycle

To describe the criteria for **battery switching stations** to comply with the needs of vehicles and infrastructure

Participant of the group are:

Renault

PSA Peugeot Citroën

Piaggio

Enel

DONG Energy

RSE

TÜV

EUROBAT

DOMERGIE

Better Place

The focus of the work concerning battery switching was on the life cycle of removable batteries as separate entity from the vehicle and technical and safety implications around batteries interfaces with the vehicle and the battery switching stations. The work of the group led to 11 recommendations of which of the following were of particular relevance to to battery switch systems:

Batteries state of health: Parameters to allow battery reuse

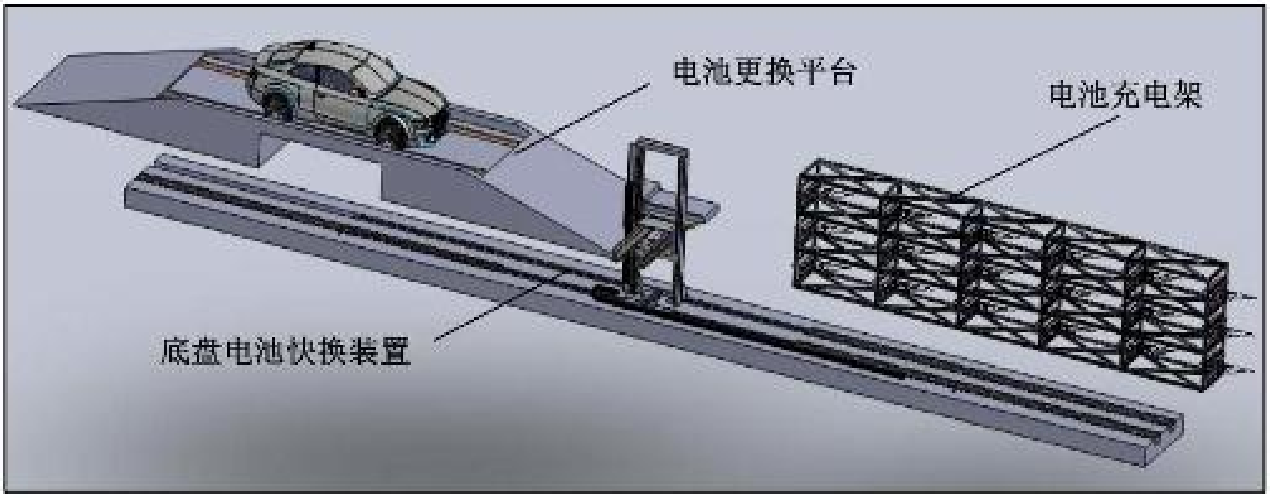
Batteries dimensions: Standardizing modules/packs sizes and interfaces

Batteries information and traceability: Minimum requirements for data collection, storage and extraction from BMS, such as ID, Alarms, temperature etc.

Batteries safety labelling

Batteries interfaces with vehicle and switching stations: Mechanical, electrical, temperature and data/communication

The standardization process within battery switching is not only limited to the work in Europe. Together with State Grid Corporation of China, Better Place has also been active in counseling and promoting battery switching within the Chinese standardization bodies. This has led to the QC/T840-2010 "Dimensions of traction batteries for electric vehicles. Moreover, another 11 standards related to battery switching technology are currently under
way:



Based on the recent establishment of Battery Switch Station Standardisation (PT 62840 in IEC TC69), there is an increasing demand to ensure interoperability with multiple cars and battery types, compliance with other standardisation requirements for battery switch while reducing facility footprint and construction costs, including the facility design, car entry lane, switching robotics, battery charging and storage.

Emphasis will be given to reducing construction costs and time span, detailed verification of compatibility with the next generation of switchable EVs currently in advanced design stages, and requirements for bi-directional chargers between EV batteries and the electricity grid. This will also include evaluation of the business case for energy storage potential in EV batteries for renewable energy integration and energy grid ancillary services. Requirements will be defined for effectively monitoring and operating the infrastructure (e.g. in remote locations or for unmanned operations), including integration to ITS management systems and backend system.

3.4 Smart Card Application Standard

This chapter describes the standard of a contactless smartcard EV application (EVAPP) to ensure that an EV charging card can be read and verified. The document introduces key concepts and then specifies the actual messages between the smart card and the CS.

Term	Definition
Charge Spot (CS)	A power outlet to which a vehicle connects and which includes an ISO/IEC 14443 type A and B contactless smartcard card reader and a communication network connecting to the card issuer.
Card	An ISO/IEC 14443 type A or B contactless smartcard.
Charge Spot Operator (CS Operator)	The organization operating the CS. A CS would normally connect to a control center operated by the CS operator and only through it to the card issuer systems.
Card Issuer	The organization that issued the card to the customer and can verify its authenticity. This organization would normally have some contract in place with both the customer and the CS operator to facilitate the use of electricity by the customer at the CS.
Verification	The process of ensuring that a card is genuine and information was not retransmitted.
EVAPP	The card application standardized in this document. This application would be issued a unique card application ID according to ISO/IEC 7816-5.
APDU	APDU stands for "Application Protocol Data Unit". A communication unit between a smartcard reader and a smartcard. The structure of an APDU is defined by the ISO/IEC 7816 standards.
RPDU	Short for response APDU.

Figure 9 – Smart card definitions

Static card information

The following information should be available on the card, transmitted to the CS and forwarded to the acquirer during a card read.

Card ID (CdID)

The card ID is send by the card both in clear text and signed as part of the cryptogram for verification purposes. The card ID is used by the CS or CS operator to route the verification request to the card acquirer.

Content

Field	Country	Operator	Card Number
Length/Range	2 characters	1-100	1-999,999,999
Description	Country code	Numerical code of the card issuer	Serial number assigned to the card
Management	According to ISO 3166[2]	Allocated by national standardization bodies.	Assigned and manage by a card issuer.

Display Format

Field	Country	Separator	Operator	Separator	Serial Number
Format/Value	String	“.”	Decimal Number	“.”	Decimal Number
Example	IL.1.14534				

Transport Format

Field	Padding	Country	Operator	Serial Number
Format	ASCII “00”	2 character ASCII string	Decimal number left padded with zero to fill 3 characters ASCII string	Decimal number left padded with zero to fill 9 characters ASCII string
Example	00IL001000014534			

Application Version

• CdVer and CdEnc are 4 bytes unsigned integers written to the card at issuing or pre-personalization and should not be writable from the outside afterwards.

• CdVer and CdEnc are sent by the card with each use and relayed to the card acquirer.

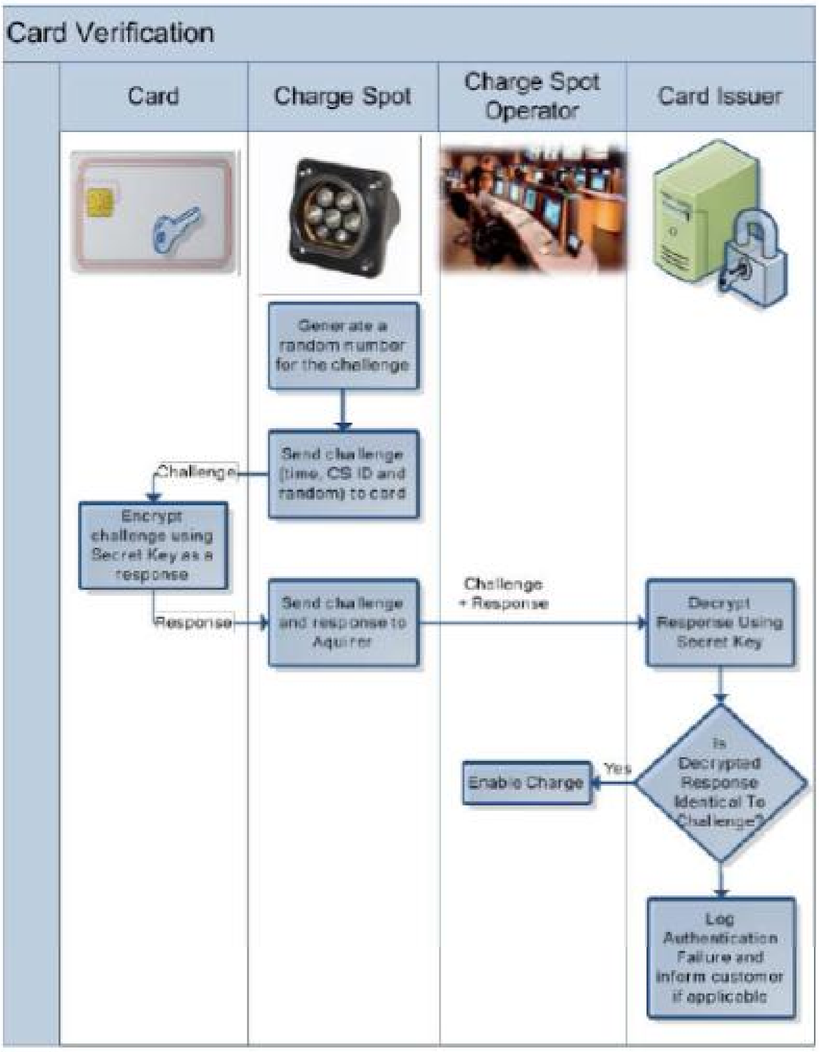
• Their use is determined by the card issued and acquirer and is opaque to CS and CS operator. These fields enable flexibility in issuing cards, which enable updates while keeping compatibility with older cards. Two use cases already identified are:

o Changing a master key: a different CdVer value could be used to indicated a different master key in case of a compromise or key distribution.

o Changing encryption algorithms: if the card is capable of more advanced algorithms, or if a flaw is found in the response generation function, CdEnc can indicate a different encryption suite.

Challenge/Response Verification

Card verification is performed between the CS, card and the card issuer using a challenge/response mechanism and the following flow. Note that the actual implementation of the response generation is internal to the card and issuer system and not part of this standard.



Card Reading Process

The card read phase will have the following phases:

Phase	Request	Response	Description
1	ISO/IEC 14443 Polling		According to the ISO/IEC 14443 principles.
2	ISO/IEC 14443 Anti-Collision		
3	ISO/IEC 14443 Activation		
4	Select EVAPP by AID	EVAPP FCI	See 0
5	Read Static Record	Card Static information	See 0
6	Perform Security Operation	Cryptogram	See 0
7	ISO/IEC 14443 Teardown		Close the connection as defined by ISO 14443.

4. Better Place Lessons Learned

The company has gained a lot of experience in putting a nation-wide, cutting-edge EV project to life. Parts of the Better Place network will continue to be operated by other service providers in the future and other battery switch technology projects will continuing to develop based on the learning from Better Place.

4.1 The Renault partnership

In Denmark Better Place had various partnerships with car manufacturers but none as extensive as the partnership with Renault. The Renault-partnership started in 2008 and was focused around building a car model and a battery switch technology to accommodate fast, safe and automated battery switching.

4.1.1 The car model

Initially, the technology was tested and developed on a converted Nissan Quasquai, which was also used for a taxi demonstration project in Japan in 2008.

For the roll-out in Denmark and Israel the already existing Renault Fluence platform was selected, a medium-sized sedan sold as ICE car in various markets throughout Europe. The model was launched as the first “ZE” (Zero Emissions) model in the Renault EV portfolio. Later came the Renault Kangoo ZE and Renault Kangoo Maxi ZE. The battery was made located behind the backseats, which resulted in a somewhat smaller trunk than in the ICE version. Besides this, the Renault Fluence ZE only differentiated by being a fully electric vehicle and by providing the driver with information about range, charging status etc. via the Better Place developed telematics system OSCAR. Besides Denmark, Israel and for the EV taxi project in Amsterdam, the Renault Fluence ZE was also launched in a number of other European markets - just without the functionality of switching the battery.

For the Danish market the selection of the Renault Fluence ZE was not an optimal choice. First of all, the Renault Fluence was not a car model that the Danish customers were familiar with in advance. But more importantly, this type of medium-sized sedans amount to a very insignificant share of the total new car sales market in Denmark. To be more successful in the Danish market, the chosen car model should have been either a small compact car or a medium-sized station wagon. The table below shows the best selling passenger cars on the Danish market in September 2012. 19 out of 20 car models are small compact models.

Number	Car model	Quantity
1	VW UP!	1003
2	TOYOTA AYGO	623
3	KIA PICANTO	607
4	CITROEN C1	520
5	PEUGEOT 107	513
6	SKODA CITIGO	495
7	VW POLO	410
8	HYUNDAI I20	365
9	KIA RIO	360

Number	Car model	Quantity
10	CHEVROLET SPARK	345
11	PEUGEOT 206	315
12	SEAT MII	271
13	SUZUKI SWIFT	244
14	RENAULT CLIO	239
15	FORD KA	230
16	FIAT 500	225
17	FIAT PANDA	214
18	FORD FIESTA	209
19	HYUNDAI I30	205
20	PEUGEOT 208	194

The top 20 car models in terms of sales figures for September 2012 in Denmark

Another disadvantage of the Renault Fluence ZE is the perception of Renault cars in general among Danish car buyers. In contrast to its French counterparts Citroën and Peugeot, Renault has always been a minor player on the Danish market.

Throughout the years, Better Place was negotiating with various OEMs about the development of new battery switch car models. This also led to a strategic partnership with Chinese car manufacturer Chery Auto. However, this never resulted in any production-ready car model. In Australia, Better Place entered into collaboration with GM with the purpose of building prototypes of their Holden brand with battery switch technology.

4.1.2 Traditional dealership model

Based on learnings from other pioneering EV endeavors, a major challenge in succeeding with the Renault Fluence ZE on the Danish market is the fact that the car was sold through traditional channels - the Renault dealerships - alongside ICE alternatives.

Educating the staff of a traditional car dealership to sell EVs is a major challenge. Even more challenging is it to motivate the sales staff of a “mixed” dealership to sell an EV rather than an ICE car.

Although, Better Place has benefited from an already existing network of Renault dealerships, Tesla’s network of exclusive Tesla stores is costly but a more powerful way to sell EVs.

One of 79 Tesla Stores around the world. The company has the same amount of services centers.

4.2 Market Strategy

Prior to the establishment of Better Place in Denmark the EV market was almost none-existing. So one of the primary tasks for Better Place was to create awareness and educate key stakeholders in driving electric. This included a broad audience, ranging from politicians to fleet owners to individual car owners. The central part of this strategy was the foundation of an EV showroom in Copenhagen, where visitors were introduced to EVs, the Better Place concept and offerings but most importantly a test drive in a Renault Fluence ZE.

The Better Place Center in Copenhagen has had more than 15,000 visitors learning about EVs and Better Place and test driving a Renault Fluence ZE during the more than two years the center was open to the public. Better Place was operating similar centers in Tel Aviv, Israel and Guangzhou, China.

Alongside, large investments in traditional and digital advertising, Better Place and EVs in general over the years, after Better Place starting business in Denmark, reached high levels of awareness and purchase desires in the public. This campaign peaked when Better Place in summer/fall 2012 went from a couple of battery switch stations to a network with national coverage.

In the months from summer/fall 2012 to May 2013, when the company filed for bankruptcy, the sales never picked up in the pace initially expected. However, Better Place managed to sell +500 subscriptions. Besides the car model, other reasons for the lack of uptake could be explained by some of the following circumstance:

Timing and launch of car model: A number of interesting car models including Renault Zoe, VW eUp, BMW i3 and Tesla Model S were all planned to launch within a year after Better Place closed down. Depending on the price level of each of these cars and the network in place to support them, they are all more attractive car models in terms of customer preferences in Denmark

Access to cars: After a heavy price reduction on the Renault Fluence ZE, Nissan Leaf, Peugeot iOn and Citroën Z-Cero in Denmark from fall 2012 and onwards, Better Place experienced huge difficulties in the supply of cars compared to the slowly rising demand. With regards to the Renault Fluence ZE, which was the most sold EV on the market, Renault Denmark could not deliver any cars for the last 3-4 months prior to bankruptcy - or at least with several months of delivery time. This was obviously not a suitable situation for ramping up sales

Public network: Better Place's huge investments in a public charging infrastructure, both charge spots and battery switch stations, was at the same time an advantage and disadvantage. For some customers this network was a key parameter, especially private customers and some fleet customers. Meanwhile, the local home care fleets turned out to be a very important segment together with private fleet owners with similar characteristics of a strictly local driving pattern. For this type of customers, the public charging network did not have the same value, and therefore, Better Place in some cases had difficulties in matching competitors, with little or no investments in public infrastructure, on price.

4.2.1 A price sensitive segment

The EV models on the market while Better Place was in business in Denmark where the Renault Fluence ZE, Nissan Leaf, Peugeot iOn, Citroën C-Zero and Mitsubishi iMiev. All of these cars compete with ICE cars in segments of car buyers, where price is a key parameter. Despite a tax exemptions on EVs in Denmark the price difference on EVs and ICE cars still didn't match the perceived benefits of an ICE car, particularly parameters as freedom to drive anywhere and, in case of Better Place, the dependency of only one provider of battery switch services.

4.2.2 Battery-switch focus compared to EV market as whole

Better Place never managed to partner up with more than one OEM to support battery switching. This was of course a key disadvantage in a market with a huge variety in offerings, particularly if this single car model is not matching customer preferences. However, Better Place from the beginning supported any other mode 3 EV on the market with AC charging. Better Place chose for a long time not to integrate fast (AC or DC) charging in its network for mainly two reason; the (few) customers using battery switching were very satisfied, fast charging was still not suitable for long-distance driving and batteries were still to expensive to apply bigger batteries in these car segments.

4.2.3 Alignment between Better Place model and OEM strategies

As mentioned, Better Place customers were very satisfied with battery switching and the network suffered from relatively few technical issues compared to the novelty of the system. There may be various reasons to why Better Place did not manage to partner with any other OEM than Renault. One central argument is the stage of maturity of EV business among the major OEMs. OEMs like VW, BMW and Mercedes are launching their first car model in 2013 and 2014. These OEMs are doing their first large scale experiments with EVs and fast charging is from such a perspective a less risky path to follow. More importantly is the fact that Better Place and Renault did not get to the stage of proofing the concept and the business in order to enable more OEMs to follow the battery switch path.

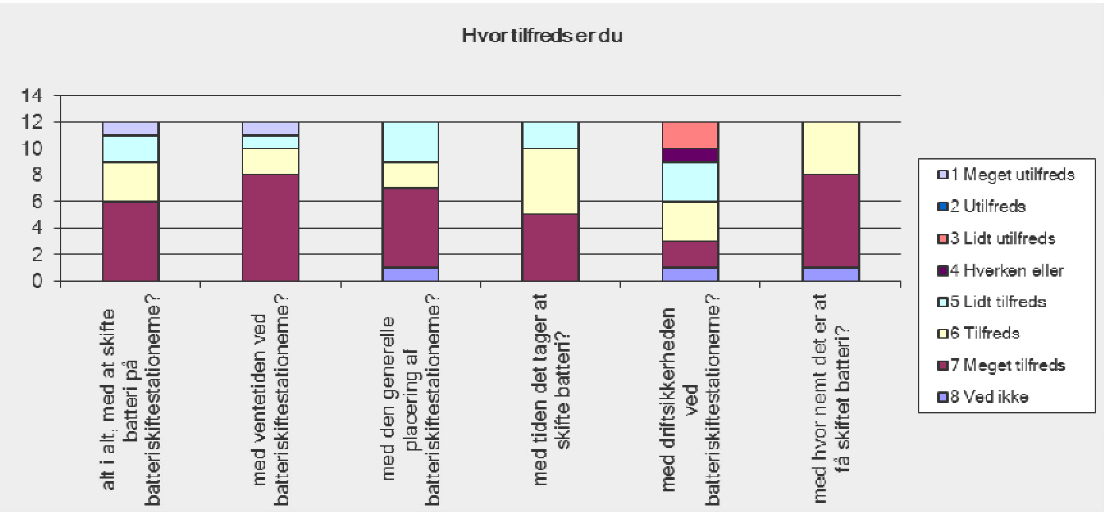
5. Future of the Better Place network

Both Better Place in Denmark and Israel filed for bankruptcy in May 2013. In the following months important events have let to renewed life of parts of the Better Place charging network.

5.1 The future of battery switching

Despite the bankruptcy of Better Place Denmark and the mother company Better Place LLC, the concept of battery switching continues to survive. Two central players in the EV industry are now integrating battery switching in their networks, Tesla and China. Moreover, parts of Better Place networks in Denmark and Israel have been purchased by new actors in the EV industry.

Despite relatively low sales figures of the Renault Fluence ZE and Better Place subscriptions, the battery switch system made the proof-of-concept in many aspects. The majority of customers were very satisfied with the battery switch station. The chart below shows the scores as of August 2012, which is the most recent assessment, carried out. The colors represent a score of 1 = ‘very unsatisfied’ and 7 ‘very satisfied’, with 8 being ‘don’t know’. The 6 categories on the x-axis represent (from left to right). Satisfaction; of switching the battery, waiting time before switching, the locations of the Battery Switch Stations, waiting time during switch, security of operations at Battery Switch Station, ease of use by switching at the Battery Switch Station.



The table shows that the vast amount of customers are overall ‘very satisfied’ or ‘satisfied’ in all of the categories, with a little less satisfaction in the category ‘security of operations at Battery Switch Station’.

Another clear demonstration of proof-of-concept is the taxi pilot at Schiphol Airport, which was implemented during the course of 2012 and officially launched in full operation on September 3rd. 2012. The pilot includes the construction of Holland’s first battery switch station for electric vehicles, located at Schiphol Airport and the taxi operations of 10 electric vehicle taxis, using the Renault Fluence Z.E., the world’s first mass-produced electric vehicle with a switchable battery. After less than two months of operation the results clearly demonstrated that the battery switch technology is able to provide range extension to the 10 taxis, and as such make them capable of having the same high service level as a traditional taxis. Overall results from the pilot, since operational opening on September 3rd 2012 to end-January 2013[1]:

237,220 e-km driven by the 10 electric vehicle taxis
3248 battery switches performed at Schiphol BSS
6274 taxi trips performed by electric vehicle taxis to and from Schiphol Airport
Max. e-km by one taxi in one day was 592 km

5.1.1 Future of battery switching network operated by Better Place

The intellectual rights to Better Place's battery switching system is owned by Better Place Switzerland. So far, no agreement has been made with any third party to purchase the IP. In Denmark, a group of Renault Fluence ZE owners have made an association to investigate various possibilities to re-launch the network. In Israel, the company Gnergy acquired the rights to operate parts of the battery switch network together with the charge spot network.

5.1.2 Developments in China

In China, the government in Beijing has for over a year been operating a network of large battery switch stations to support a fleet of electric cars, vans and trucks. The network is operated by China's largest grid operator State Grid Corporation of China. Better Place has over a longer period been working closely together with State Grid on battery standardization efforts. State Grid is now expanding their activities to include cooperating with various OEMs and local governments beyond Beijing to launch battery swapping demonstrations, both for buses, trucks, passenger cars and commercial vehicles[2]

[1] Analytics collected by the Better Place NL Network Operations Center (NOC)
[2] http://www.cse.anl.gov/us-china-workshop-2012/pdfs/session3b_demos_standards/hua_3B-4-HUA-Tsinghua%20Univ-Progress%20in%20Battery%20Swapping%20Technolo.pdf

One of State Grid Corporation of China's demonstration projects on battery switching.

SGCC's strategy with battery switch stations is somewhat different. The SGCC approach consists of the following key elements:

Battery swapping as main energy-refueling

Plug charging as auxiliary energy-refueling

Centralized charging for batteries

This map shows some of the demonstration projects that SGCC is running with regional partners and OEMs in China:

Company	Logo	Belongs to	Battery Swapping Tech. Provide	Cooperator
Key Power Tech.	KeyPower 科易动力	Independent	For Passenger Vehicle	KIA 东风日产
XJ Group	许继集团	Belongs to State Grid	For Bus	
DB Tech.		Independent	For Commercial Vehicle	
HEPSTD	HEPSTD	Belongs to State Grid	For Passenger Vehicle	Haima 海马汽车 众泰汽车 ZOTYE AUTO

5.1.3 Tesla announcements on battery switching

Shortly after the bankruptcy of Better Place Tesla Motors revealed a plan to roll out battery switching stations as an alternative to their network of Tesla Superchargers. The event included a live demonstration of two Tesla Model S cars switching battery on stage. The plan so far for Tesla is to offer battery switching at a certain price, where as the Tesla Superchargers are for free. Tesla indicates on their website that they can manage to switch battery on a Model S in 90 seconds.[3]

According to Tesla, a number of Supercharging stations on West Coast and East Cost of USA will be expanded with battery swapping stations already by the end of 2013 and will expand further in 2014. Tesla expects the price of a battery swap to be around 60-80 USD. The customer swaps the battery while driving to a certain destination and returns it on the way back and receives the original battery in a fully charged state.

[3] http://www.teslamotors.com/batteryswap

The first demonstration of a Tesla Model S switching battery from June 2013.

5.2 The future of charging networks operated by Better Place

5.2.1 Denmark

In Denmark, the network of 770 Better Place charging stations (each with 2 outlets) has been purchased by E.On, one of the world's largest electricity companies. E.On Denmark informs on their website that they will soon be launching a number of EV services including a personal site online to administer account, invoices and to monitor energy consumption, an interactive map of charge spots as well as a mobile app.

5.2.2 Israel

In Israel, Carosso, which is the Israeli Renualt importer and dealer, committed to continue the service to all 900 Fluence Z.E in Israel, and also bought from the liquidator of Better Place the remaining 359 unsold cars that were in the ownership of Better Place Israel, which at the time of bankruptcy not yet delivered to customers. As mentioned, the Israeli company Gnergy has acquired the rights to operate the network of charge spots as well as parts of the battery switch stations.

5.3 Other EV initiatives in Denmark

Denmark has been at the forefront of commercializing EV for the last 4-5 years since Better Place decided to launch in Denmark. Even though the bankruptcy of Better Place was a major drawback in terms of investments, infrastructure coverage, sales and marketing push, technological development and industrial partnerships. However, alternatives to Better Place remain. The latest entry on the market is EON, who as mentioned has invested in taking over Better Place charging network. Another important player on the market is the privately held company CLEVER, who is operating a nation-wide network of 50 fast charging stations as well as a number of slow charging stations. The company is partly owned by the five electricity companies SEAS-NVE, SE, EnergiMidt, EnergiFyn and NRGi. The company has strategic partnerships with both Nissan and VW but serves any modern EV on the market. The company is offerings its customers a range of different solutions including charging at home, charging on the go and all-inclusive. The company is also initiator behind Europe's largest EV testing scheme. Since 2011 the company has engaged in partnerships with local companies and authorities to offer private households and fleet owners to borrow an EV for three months. Since 2011 the project has achieved a number of remarkable results:

- Participation by 25 municipalities, 3 hospitals and a large number of local companies
- Participation by 1,400 private households and 25,000 applications from families to participate
- 200 EVs are constantly circulating among test drivers
- 3,2 mio kilometers have been logged
- The project will continue to run until 2014

Another player is Cleancharge, which is smaller network operator primarily focused on operating private charge spots, e.g. for the Danish Postal Service and City of Copenhagen. Also, the company is focusing on deploying open pay-as-you go infrastructure. The company has a partnership with RWE and is mainly using the hardware and software of the German electricity company.

TUXI is the name of another actor on the Danish market. TUXI is an EV car sharing scheme that is planning to launch in various markets across the world. The primary focus is to launch the concept in Copenhagen and Lisbon, but the operator is also establishing license agreements in Brussels, Lyon, Rotterdam, Milan, Mexico City, Bogota, Beijing and Shanghai. The operations in Copenhagen and Lisbon are scheduled to launch in early 2014. In Copenhagen TUXI is currently testing its concept in small scale on the island of Bornholm and next stage is to launch a Copenhagen-based operation of 150 EVs. The concept is based on a “free-flow” concept, where cars can be picked-up and dropped-off on any of the dedicated EV spots across the city. Cars will be rented per minute. TUXI also offers company customers to operate dedicated fleet EVs but only paying for the actual usage of the car.

Besides a number of EV and charge spots operators in Denmark, another player in the market to mention is the charge spots manufacturer EVergreen.

Conclusions

This report included an evaluation of Better Place’s service provider model deployed in Denmark from 2008 to 2013. Better Place offered customers a new way of driving by reducing cost of driving electric by taking over the ownership of the battery and leasing it to the customer on a monthly subscription that was bundled together with electricity and access to a home charge spot, a network of public charge spots and 18 battery switching stations across the country. In this way, Better Place Denmark was Europe’s first national network for fully electric driving.

More than 2M eKM were logged through the Better Place Network Operations Centre and more than 20.000 switches were performed on the network of BSS.

Another significant proof of concept was the Amsterdam Taxi Project. In 21 months 1o taxis were used as regular taxis to /from Amsterdam Airport. The 10 EVs achieved in 21 months 237,220 electric km and 3.248 switches at one single battery switch station placed at the airport. The maximum km range per week is of 2.412 km per car. In a year the average km per car would be approximately 80.000 km per car.

In the aftermath of the liquidation of Better Place, the operations of charge spots and battery switch stations continue in Israel. In Denmark Europe’s largest energy company

E.On has acquired the network. Moreover, recent developments in China and the US (Tesla) shows that the concept of battery switching continue in different models.

The key lesson learned based on the Better Place activities in Denmark is that battery switching works as an infrastructure for long distance electric driving. Even though Better Place experienced great customer feedback, Better Place acquired too few customers. This report pinpointed some of the learnings that might explain why. Some of the most important learnings are the difficulty of selling EVs in traditional dealerships, the challenge of bringing such a concept to the market with a less popular car model and the consequences of positioning such a product as electric driving in a very price sensitive market segment.