Electric Mobility Needs Smart Infrastructures

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Summary

We provide a first status on four key claims on smart infrastructures for electric mobility in built environments: 1) electric vehicles need to be smartly integrated into the electric power grid, 2) the charging infrastructure as such needs to be available and smart, 3) the urban and environmental impact can be balanced and 4) a healthy and profitable electric mobility value network can be developed and implemented. Our analysis shows that for the real estate, construction and facilities management industry a whole gamut of business opportunities through e-mobility is opening up.

Keywords: electric mobility, sustainable mobility, smart grid, sustainable community, electric vehicle, value chain, value network, smart charging

1. Introduction

1.1 Background

Human mobility is a major issue in the ongoing discussion and research on sustainable living. Whereas we recognise voices asking for a general reduction of mobility, the overwhelming majority of this planet's population connects mobility to freedom, and thus shows little interest in reducing mobility from an individual's point of view [1].

In this context we call for sustainable mobility in sustainable communities, without propagating the reduction of mobility per se. We know that achieving sustainable mobility, without reducing mobility, is an extremely difficult task and maybe even impossible. Still, we take on this challenge.

Of all possibilities available for making mobility more sustainable, we have chosen deliberately the electric engine, connected to a battery. Thus in our focus are electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs). All other vehicles, without the ability to connect to the electric power grid, are not in our scope.

1.2 SIMBe Consortium and Project

We are a multidisciplinary team of researchers, complemented by Finnish industry: teaming up with the city of Helsinki and companies such as Helsingin Energia, S-Group, Nokia Siemens Networks, Ensto, Puronovo as well as the Finnish Parking Association, European Batteries Oy and various e-car service providers, are four Aalto University School of Science and Technology units.

They include the BIT Research Centre, the New Energy Technologies group, the Transportation Engineering unit and the department of Electrical Engineering.

Our two-year research project is named SIMBe: Smart Infrastructures for Electric Mobility in Built Environments. Its major funder is the Tekes Sustainable Community programme.

1.3 The Smart Electric Mobility paradigm

We propose the following, slightly simplified, four key claims, formulated as a paradigm:

Smart electric mobility can be environmentally neutral, even sustainable and affordable, if…

1. *EVs are smartly integrated into the electric power grid,*
2. *the charging infrastructure as such is available and smart,*
3. *the urban and environmental impact is balanced and*
4. *if there is a healthy and profitable e-mobility value network developed and implemented.*

In the following we provide a first status on these four key claims, by synthesising the first results following eight months of SIMBe project collaboration. Furthermore we will derive some first recommendations towards the real estate, construction and facilities management industry.

1.4 Methodology

For each of the claims above we have launched a dedicated work package with detailed task descriptions and deliverable requirements. All of these four work packages have started with a literature study. Within the three first, technology oriented, work packages we apply existing and proposed standards when performing own calculations and performing digital simulations of, e.g., grid effects. As much as possible we use real-life data available from public and company sources. In the value networks work package we gathered and validated qualitative data by performing interviews with 11 internal and 27 external SIMBe stakeholders. Eight of these operate only outside of Finland and one (the KEHTO/KUPERA project) represents the 18 biggest cities in Finland. Still in 2010 we will launch an end-user survey, complemented possibly by a set of end-user interviews.

2. The Electric Power Grid View

The major strength of an EV towards the grid is its capacity to buffer electric energy. And as private cars remain about 90 per cent of their time stationary [2], these buffers are available for a large range of use. However, they need to be plugged in (see next chapter).

In the short term, when a majority of private e-cars will be only the secondary car in a household, there will be even a large number of cars available – stationary – during the times of rush hours.

The paradigm change is the following

- EVs can provide energy, they can feed up to the grid
- The grid becomes smart – and EVs play an active role
- Electrical, renewable energy can be buffered – by EVs
- Thus local and distributed energy production is welcome, virtually at any time

Fig. 1 A stationary car acting as a buffer for the electing grid

There are hundreds of smart grid projects under way, world wide, e.g. in Helsinki the Kalasatama hanke (https://www.helen.fi/pdf/Suvi10_hyvarinen.pdf). However, only a very limited number of those projects involve EVs from the very first stage. One example is the Pecan Street Project (http://pecanstreetproject.org).

From a grid point of view, the main goal is to reduce the number of peak loads and to reduce overall production energy consumption as well as emissions. The individual smart grid objectives, when involving EVs, are:

- Reduce peak loads, as they cause in general the highest CO_2 emissions (e.g. through usage of gas turbine powered plants)
- Use renewable energy when available, e.g. wind, solar or water energy
- Consume otherwise unused energy: under certain circumstances, nuclear power plants produce more energy than needed. Also the power of water reservoirs is sometimes left unused, especially in night times during spring.

Our first computer aided simulations of the impact of EVs on the power supply grid show clearly, that EVs without the capability of feed-up, and a grid without asking for feed-up, will be counter-productive. The ideal impact of EVs (blue curve in figure 2) can be achieved only by smart interaction between grid and EVs.

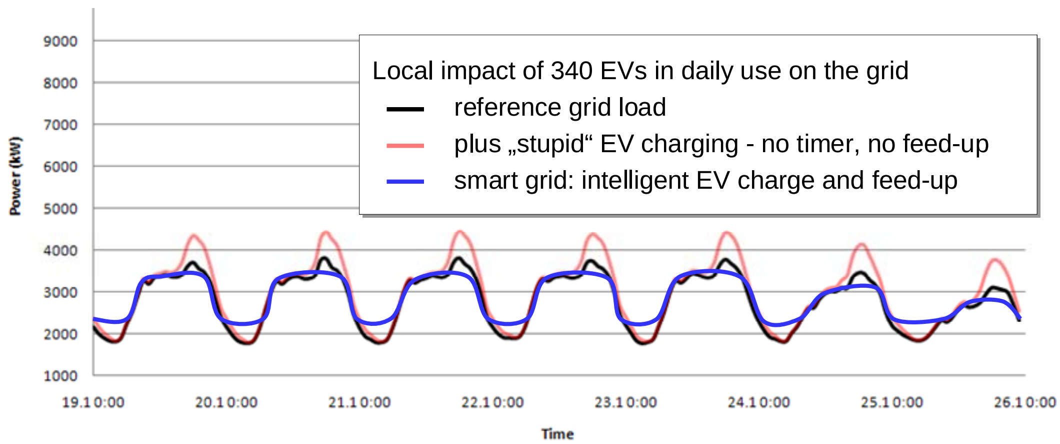

Fig. 2 SIMBe simulation of grid power supply within one week in a local community

Our next simulations will concern suburban areas (individual view and medium voltage feeder) and downtown areas. Simulations taking Helsinki as location have been launched already. Note that the quality of the grid power (i.e. the overlay of the various phase curves) needs to be considered as well.

3. Charging Infrastructure

3.1 Individual EVs

We consider slow and fast charging and its effects on the grid and the batteries. If the smart grid model is to be successfully applied, charging opportunities are needed in

- Public, private and work place related parking lots and garages,
- park-and-ride places and
- curb-side

Furthermore, the following additions to the pure power plug-in are needed:

- smart charging and feed-up means – both as hardware and software
- billing and metering and means of payment
- reward mechanisms for EV owners – especially for plugging-in stationary EVs

Curb-side charging creates the biggest challenge, as – even in Finland – there is no existing infrastructure on road sides for plugging in EVs. Research is needed on how to address all the related issues.

The second biggest challenge is about driver's mindsets regarding stationary cars. With which reward mechanisms can they be convinced that locking and plugging-in goes hand-in-hand?

Table 1 provides an overview of the currently discussed charging modes, along with theoretical charging times, calculated for 90% charging efficiency.

Table 1 Calculated min. charging times using the modes proposed in the IEC 61851-1 standard

Mode	Max. Voltage	Max. Amperage	Max. Power	Min. Theoretical Charging Time	
				20kWh capacity	30kWh capacity
1	230-400V	16A	3.7-11kW	2-6h	3-9h
2	400V	32A	13-22kW	35-60min	53-90min
3	690V	32-250A	22-300kW	5-60min	7.5-90min
4	DC 1000V	400A	400kW	3.5min	5min

3.2 Public and Delivery Transport

Our research scope in this area encompasses the following EV types:

- Trolley buses with range extension battery
- Battery powered buses
- Battery powered delivery vehicles

Table 2 provides a first overview of alternative bus concepts, based mainly on literature research. More criteria, such as maintenance costs, comfort and attractiveness and further environmental criteria will be added.

Table 2 SIMBe's bus power source evaluation [3]

Criteria	Overhead (Trolley)	Hydrogen	Battery
Energy balance (consumption in kWh/km)	+ (1.8-2.5) (transformers and lines create some losses)	-- (3.9-6.4 with fuel cell)	++ (1.0-1.2)
Volumetric storage density	++ (no dedicated storage needed)	+	--
Technological availability	o (a few experienced manufacturers)	-	-
Range	++ (unlimited range but restricted routes)	o (similar distances to diesel buses)	-- (limited)
Additional infrastructure	- (overhead lines; supportive structures)	- (storage; dispending)	- (recharging; battery swapping)
Unit costs (in 1000€)	- (450–750)	-- (805–2410)	- (204 for small bus; 383 for hybrid)
Working as power resource	Not possible	Not considered	+ (supports smart grid)
Legend: -- major disadvantage; - disadvantage; o neutral; + advantage; ++ major advantage; verbal remarks for further clarification. Reference: diesel bus with unit costs of €250,000-300,000; consuming 4.5-5kWh/km			

3.3 Battery Switching

Another way of charging energy into EVs is simply to switch the batteries. This has been taken into operational use e.g. in Tokyo, with *Better Place* acting as system integrator and provider [4].

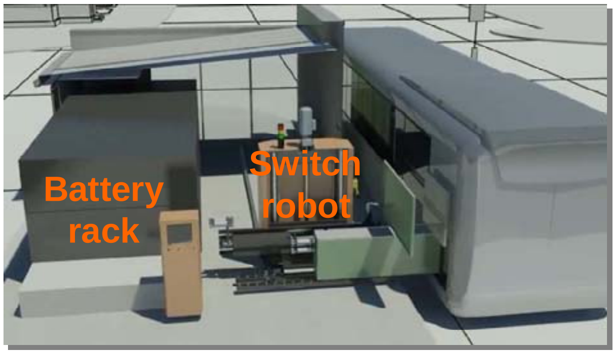

Fig. 3 Battery rack and battery switch robot for buses in action (courtesy Puronovo Oy)

The benefits are easily identified: the charging time equals today's refuelling time for a combustion engine vehicle. Thus swapping is attractive for large EVs with large battery capacities (>100kWh) and in general EVs that are in professional "around the clock" use, typically taxies. Another benefit is the resulting battery rack as such. This rack of either charging or waiting-for-swapping batteries can act again as a grid buffer. And even more interesting, a large rack of batteries allows the provision of fast charging for standard EVs (e.g. 60 batteries fast charging one battery). However large car manufacturers show little interest in switching, as standards are missing and consumers seem not yet prepared.

4. Urban and Environmental Impact

The environmental component is obviously the most relevant trigger for e-mobility. Alongside the environmental impact, also mobility in urban areas as such needs to be evaluated.

Our research on future urban mobility touches the general question of the human yearning for mobility, the future role of the (individual) car and the emerging new EVs and EV concepts. We will conclude by outlining the effects of e-mobility on people's mobility and on their selection of transport means. Here we also address combination of travels, such as light electric vehicles plus public transport plus parking; effects on traditional public transport, e.g. replacement by light city vehicles; new types of public transport solutions incl. demand based mini-busses and automatic transporters; and the convergence of land use.

The research on traffic and transport integration focuses on urban traffic flows and travel behaviour, based on data taken from the Helsinki metropolitan area traffic survey. Various scenarios for penetration speed of EVs are to be established. The next output will be a blueprint for the local charging network.

In parallel, we are conducting an environmental assessment covering the whole EV life cycle, including the emission view on electric energy creation.

5. Electric Mobility Value Network

5.1 Underlying Theory

Value chain analysis in academic discussion was started by Porter in 1985 [5]. He intended to cover the activities within and around an organisation which are directly linked to its competitiveness. Today the value chain concept is widely used in business management and has been applied to many contexts. Porter's value chain analysis has evolved to more advanced value chain techniques, e.g., Loebbecke [6] used a product's industrial value chain for locating different stakeholders and their strategic role. Still, the key thought in value chain analysis is how the chain links and the composition of the links add value to the entity. A company's value chain is typically part of a value network describing the activities between suppliers and buyers. The down stream and up stream linkages can provide new opportunities for a firm to enhance its competitiveness.

The individual value chains of different companies within an industry vary. Also the value chains of different industries vary based on the particular characteristics of the industries. It is important to define the overall industry value chain, as the differences between the chain links visualise the source of competitive advantages between the value chain participants.

5.2 The Generic Industrial Electric Mobility Value Chain

In the first SIMBe project deliverable [7] we used the generic industrial value chain approach to unravel the complexity in e-mobility, including a first description of the actors and their value adding activities toward the end customer. In this section we draw from these results, focussing on the impact on sustainable communities, including real estate, construction and facilities management industry.

The purpose of the generic industrial e-mobility value chain as presented in figure 4 is to identify required elements (roles, participants, services, products) to enable the introduction of EVs. Diffusion of EVs is directly dependent on the services and other applications related to EVs. Consumers will only adopt e-mobility if the complex entity of using EVs is offered well-designed. This is not possible without extensive supply of needed elements and collaborative business between chain links. All the parts of the value chain need to be covered – without a solid chain there will not be sustainable business.

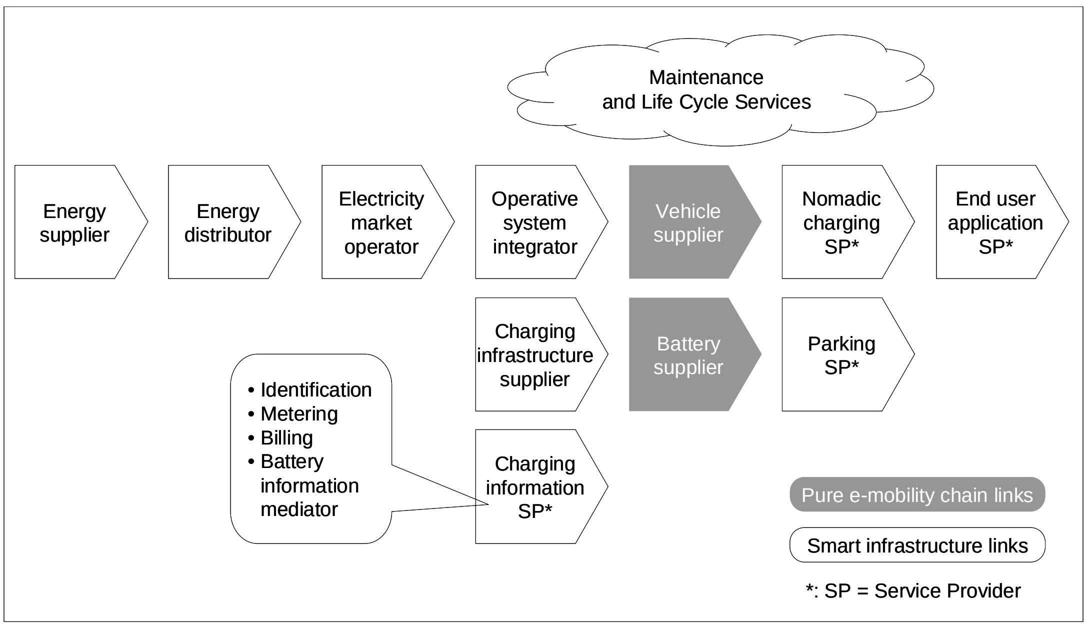

Fig. 4 Generic industrial e-mobility value chain, highlighting smart infrastructure links

The generic industrial e-mobility value chain is the output of the stakeholder interviews, applied to Porter [5] and Loebbecke [6]. Currently, it is in the process of being validated by the interviewed stakeholders. In figure 4 we highlight the chain links connected to smart infrastructure. They are largely independent from e-mobility; however e-mobility relies on them.

5.3 Value Creation Opportunities

In the following we outline how the actors in value chain can add value through taking on their respective roles in the chain.

Energy supplier and **energy distributor**: the smart grid will add value for the e-mobility value chain by making use of the EVs' batteries as explained in chapter 2 of this paper. These benefits help reducing emissions and saving costs.

The **electricity market operator** will add value by providing the information needed as well as controlling the charging and feed-up timing as needed. This will serve the interests of both electricity producer and distributor, and thus can be monetised.

The **operative system integrator** will play a central integration role. Besides conducting the operative tasks of charging infrastructure installation, another task is to ensure that the value chain for charging EVs is sound. Thus the operative system integrator mainly adds value in supporting other value chain actors' functions. This value can be monetised.

Charging infrastructure suppliers will add relevant value to the e-mobility value chain by providing the physical means for charging. They need to collaborate closely with other value chain actors, such as charging information service provider, energy supplier and distributor as well as vehicle and battery supplier. Particularly the EV charging infrastructure needs to respond to smart grid requirements.

Charging information service provider: the smart grid needs real time information about electricity supply and demand – both from the (integrated) grid view as well as from the individual EV. All interaction between the battery, charging device (and station), electricity distribution network and electricity producer is dependent on the information service provider role. This role will add value by serving the different operators and clients with a smooth, adaptable communication platform. This service can be monetized.

Nomadic charging service provider: we use the term nomadic charging to describe charging away from home or workplace. The existing fuel station network could be a future EV charging service provider, complemented by, e.g., supermarkets, shopping centres and other public areas with large garages and/or parking lots. The monetising clue is the "full battery, here and now" requirement, which allows asking for a considerably higher fee per kWh than usually.

Parking service provider: already today selected car parks and parking garages, also in Finland, offer slow charging during parking. In the future this can be extended in volumes and also in speed (of charging). Ultimately a parking service provider can become nomadic charging service provider.

End user application service provider: EVs are most suitable for urban traffic due to their inexistent exhaust emissions. Thus EVs are ideal for urban car sharing clubs and car rental agencies. Also hotels and further real estate and utility providers can certainly realise the opportunity to provide EVs to their urban customers. EVs will be suitable for collecting traffic in context with railway stations for commuter traffic as well as long distance traffic. Thus for the real estate, construction and facilities management industry a whole gamut of business opportunities through e-mobility is opening up right now. Note that the market will gradually become end-user driven – they ask for clean mobility, including smart mobility, and they will be ready to pay for it.

Maintenance and life cycle services are usually integrated in various chain links. These services could be provided by the original supplier of the product (e.g. charging device/pole) or separately (e.g. car repair shop), as well as centralized (e.g. battery recycling).

6. Discussion

6.1 Limitations

This paper is providing an interim status and is limited to EVs and PHEVs as defined in the introduction. We assume that in the mid term the smart grid will include EVs. Thus the large car manufacturers need to provide EVs capable of battery feed-up to the grid. If they fail to so, for whatever reasons, e-mobility will hardly be sustainable.

As the progress in e-mobility is rapid, there is a high risk of information to be outdated. However, technological evolution will rather support our claims. In the following 16 months we will carry on with our research, taking further stakeholder and end-user comments into account.

6.2 Conclusion

E-mobility needs smart infrastructures

EV batteries offer huge opportunities for grid and sustainable mobility, under the following pre-conditions: intelligent, smart charging management solutions and sufficiently many charging and feed-up possibilities in work places and especially on curb sides are provided. Feed-up capability is a must for all new buildings and grids. Future "fuel-stations" will need at least 1.2MW charging power capability. Battery racks (buffers) must be multi-use and multi-feed.

E-mobility provides earning opportunities

The industrial e-mobility value chain is not yet implemented. This means also that the related business models are not yet clearly defined. Still, the chain indicates that there will be good business opportunities for various actors in the value chain in the mid term.

For real estate, construction and facilities management industry a whole gamut of business opportunities through e-mobility is opening up. Urban car sharing clubs and rental agencies, along with hotels and railway station operators are engaging already. Note that the market will gradually become end-user driven – they ask for clean mobility, including smart mobility, and they will be ready to pay for it.

The most interesting role, combining the potentially highest earning opportunities and risks is the operative system integrator. Only one, globally operating, company has taken up this role yet: Better Place. We recommend establishing competition – starting locally in Finland.

General recommendations

When connecting EVs to sustainable communities and building, think holistic and allow complexity. Think big and international and listen to stakeholders. Find the business perspective: visit www.SIMBe.fi and become a stakeholder.

Acknowledgements

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