# Urban Network Infrastructure

## Sharing of Charging Current and Exploiting Utilization Potential

Kira Rambow-Hoeschele
Robert Bosch GmbH, Gerlingen-Schillerhöhe, Germany
Glasgow Caledonian University, Glasgow, UK
Aalen University, Aalen, Germany
kira.rambow-hoeschele@de.bosch.com

Dr. Karlheinz Bozem
bozem | consulting associates | munich, Munich, Germany
Research project partner of the cooperative BMBF project "low-carbon city", Aalen University, Aalen, Germany
bozem@bozem-consulting.de

Prof. Dr. Anna Nagl
Academic dean and leader of the
Competence Center for Innovative Business Models
Leader of the cooperative BMBF project "low-carbon city"
Aalen University, Aalen, Germany
anna.nagl@hs-aalen.de

Kevin Braun
Research associate of the cooperative BMBF project "low-carbon city", Aalen University, Aalen, Germany
kevin.braun@hs-aalen.de

Peter Hoch
Research associate of the cooperative BMBF project "low-carbon city", Aalen University, Aalen, Germany
peter.hoch@hs-aalen.de

Prof. Dr. David K. Harrison
School of Engineering and Built Environment
Glasgow Caledonian University, Glasgow, UK
d.k.harrison@gcu.ac.uk

Prof. Dr. Bruce M. Wood
School of Engineering and Built Environment
Glasgow Caledonian University, Glasgow, UK
b.m.wood@gcu.ac.uk

***Abstract*—The Competence Center for Innovative Business Models at Aalen University researches and develops new, economically resilient business models for sustainable electromobility. Ecological possibilities to charge electric vehicles with solar power are investigated. This paper deals with solutions on how to increase the utilization rate of charging stations and how to better use renewable energies for the supply of such. The project is state subsidized by the German Federal Ministry of Education and Research (BMBF) from August 1, 2016, to December 31, 2018, under the references 02K12A150 and 02K12A151. In the context of the research project, business models are developed that generate added value for the stakeholders such as electric vehicle users, grid operators, energy suppliers, and other companies.**

***Keywords-electric vehicles; charging infrastructure; grid integration of large-scale electromobility solutions; innovative business models; market design; power system integration and operation; stakeholders of the renewable energy industry***

## I. INTRODUCTION

Within the research project, network infrastructures in diverse areas (small, medium-sized, and large cities) are investigated for their potential of increasing electromobility. Especially in areas with high population density, the network infrastructure needs to be prepared for the additional electrical load resulting from the increasing number of electric vehicles. Applying the Business Model Builder © [1], a business model was derived to solve the potentially dangerous grid overload. The Business Model Builder is a business model design tool created within the research phase by the project partner and CEO of the top management energy consulting firm bozem | consulting associates | munich,

The business model derived allows to use the photovoltaic electricity generated in areal grids and multi-family houses at one or more charging stations. In particular in older multi-family houses with underground parking, infrastructure problems will arise because the electricity supply lines are not originally intended for higher demand such as are charging stations or wallboxes.

The self-produced photovoltaic electricity enables the usage of charging capacity higher than the electrical output of the underground parking. The charging station as well as the photovoltaic charging electricity are shared by the users. Hence, multiple advantages emerge for the stakeholders of the business model:

For owners of photovoltaic plants: If the electricity within an areal grid or a multi-family house is used and not fed into the public electricity grid, there is no charge for the network utilization. The photovoltaic electricity can directly be used on site and hardly any financial apportionments, e.g., from the network utilization or the Renewable Energies Act (EEG) [2] reallocation charge, apply.

This constellation represents a sales opportunity for the photovoltaic electricity exceeding the EEG tariff. For photovoltaic plants falling out of the EEG remuneration due to their age, the sales opportunities generated through this business model are often more attractive than a direct marketing of the electricity produced.

For the users of the charging stations: "Sharing" charging stations implies a higher utilization rate of such, amortizing investments faster. Charging electricity from a photovoltaic plant, not transported through the public electricity grid, results in reduced charges, allowing a cheaper sourcing of electricity. The cost-reduced charging electricity shortens the amortization period of an electric vehicle.

## II. Research Approach

An increasing number of electric vehicles to be charged means that the network infrastructure has to manage an increasingly growing current load. Hence, the research project "low-carbon city" ("$CO_2$-arme Stadt") [3] investigates network infrastructures in diverse areas (countryside, medium-sized, and large cities) in regard to their compatibility with the growing load caused by the advancing electromobility. The challenge of the additional electric load especially concerns more densely populated areas. Moreover, multi-family houses with parking spaces often face infrastructure problems when supply lines are not designed for larger electricity consumption from charging stations or wallboxes, for example.

To relieve the network infrastructure accordingly, sophisticated business models and technical solutions are required. These solutions have to be developed and matured at an early stage to be prepared for a potentially strong growth of electric vehicles.

## III. Methodology

The business model derived within the research project "low-carbon city" was developed on the basis of the so-called Business Model Builder © [1]. This tool for business model design was built by the project partner and CEO of the top management energy consulting firm bozem | consulting associates | munich during the research phase.

The Business Model Builder serves as both practice-oriented and cross-industry action guidelines applicable to the development of innovative business models. The purpose is the advancement of a fundamental business idea, e.g., supported by state-of-the-art methods such as Design Thinking [4] or Open Innovation [5]. The aim of this further development is a comprehensive qualitative description of the business model and the quantification by means of a business case testing if a business model is financially sustainable.

## IV. Development of the Business Model for Charging Current Sharing

Preparing for an increase in the number of electric vehicles to be charged, a business model is developed within the research project "low-carbon city" enabling the charging of electric vehicles with green electricity self-produced by the community, i.e. among neighbors. Under this so-called "charging current sharing in areal grids", the electric vehicle is charged with photovoltaic electricity self-produced, e.g., in residential complexes or industrial parks, representing the areal grid.

In this business model, the charging infrastructure and the production potential are used by a group formed of locally close units, as shown in Fig. 1. This setup results in the decisive advantage of relieving the network infrastructure. The electricity generated does not need to be transferred over long distances anymore, but is directly consumed within the immediate surroundings. Thus, the load of the higher-level network is reduced.

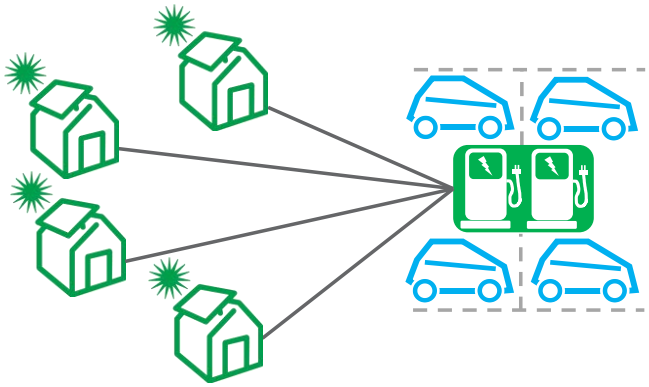

Figure 1. Charging current sharing in areal grids: Charging of electric vehicles with green electricity self-produced by the community

## V. Empirical Evidence

The business model developed by means of the Business Model Builder allows transferring and using the photovoltaic electricity generated within areal networks and multi-family houses at charging stations within the local surroundings. This method makes charging current levels possible which are much higher than what the supply line of a multi-family underground parking garage, for instance, could process. Both self-produced photovoltaic electricity and charging stations are shared among the users.

The customer acceptance of this business model was empirically confirmed through a written survey of 1,305 customers of the regional distribution grid operator Überlandzentrale Wörth/I.-Altheim Netz AG (ÜZW) in October 2016 within the cooperative BMBF project "low-carbon city".

Fig. 2 shows that 83.7 % of the sample are willing to let their neighbor use their charging station. While 88.2 % are willing to sell their self-produced photovoltaic electricity at a cooperative charging station, 78.0 % are willing to charge their self-produced photovoltaic electricity at such a charging station.

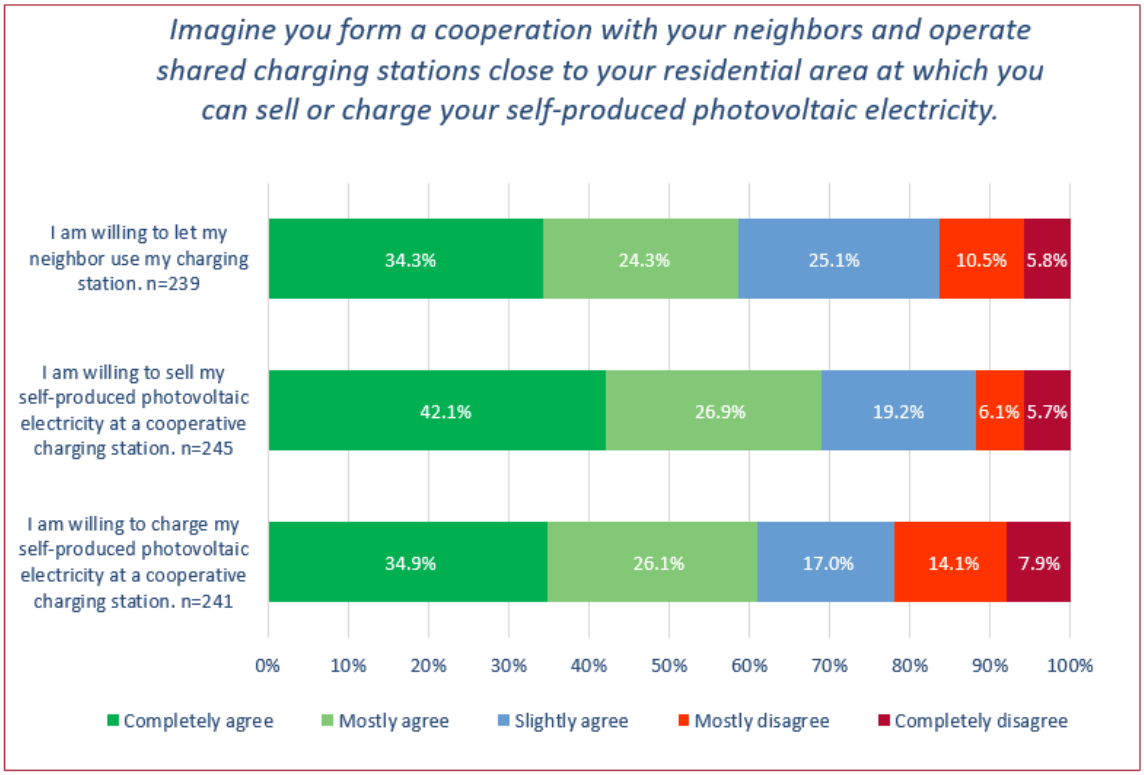


Figure 2. Survey on the customer acceptance of the business model "charging current sharing in areal grids"

## VI. Stakeholder Ecosystem

For all stakeholders of the business model, advantages arise. From the customer perspective, the following two stakeholders play the main role.

### A. *Photovoltaic Plant Owners*

Using the self-produced photovoltaic electricity within an areal grid or multi-family house, fees of using the public electricity grid do not apply. The usage of the electricity on the production site has hardly any apportionments, such as the EEG apportionment. This creates a new sales opportunity of remaining self-produced photovoltaic electricity which is higher than the EEG remuneration. Under the consideration that many photovoltaic plants will fall out of the EEG remuneration due to their age, an opportunity emerges for the photovoltaic plant owners which is more attractive than the direct marketing.

### B. *Charging Station Users*

Charging stations are still relatively costly. Sharing charging stations increases the utilization significantly, amortizing the investment into a charging infrastructure faster. The self-produced photovoltaic electricity, to be used within the areal network as charging power, underlies lower charges as discussed in the section above. Consequently, the locally-produced electricity can be obtained cheaper by electric vehicle owner who charges locally than if he obtains the electricity from the public network. This also reduces the amortization time of the electric vehicle.

## VII. Implementation of the Business Model and Conclusion

Within the research project "low-carbon city", a pilot project of this business model was developed theoretically and tested. However, a practical implementation of the business model is yet to follow. The reason behind are the structural conditions in the network area of the project partner ÜZW which have not been ready yet for implementation during the project timeframe.

The business model creates added value of both monetary and non-monetary nature for all stakeholders. The network operator profits from the relief of the network. A financially resilient implementation, nonetheless, will only be possible as from the year 2020 when photovoltaic plants start falling out of the EEG remuneration. Furthermore, regulatory changes on the energy market toward electromobility have the potential to positively impact the business model developed within this research project.

## References

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