EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

Integrated Mobility and Energy Infrastructures – Assessing Centralized and Decentralized Grid Integration of EVs

Sven Lierzer[1], Alexander Schuller[2], David Dauer[2]

[1]*BridgingIT GmbH, Marienstraße 17, 70178 Stuttgart, sven.lierzer@bridging-it.de*

[2]*FZI Research Center for Information Technology*

Abstract

The Project IMEI addresses several challenges that arise from the grid integration of EVs. In particular two main settings for EV adoption are investigated. First, a decentral, end consumer focused scenario including small and medium customers is evaluated w.r.t. to the effectiveness of a distributed, swarm based charging management program. Second, a centralized EV-fleet charging control that is collocated with in a microgrid setting is evaluated. Both scenarios are assessed w.r.t. their ability to use locally produced renewable electricity and their consideration of grid constraints. Furthermore, user interfaces for these scenarios and different business cases are evaluated in this context.

1 Motivation and Background

Electric vehicles (EVs) must be integrated in increasingly higher numbers into the power grid. Currently the adoption is rising but mostly does not pose a threat to local grid supply capacities. Due to the increase in the number of available models and the decrease of costs for the respective vehicles, this is likely to be very different in the near future. It is thus necessary to develop mechanisms to efficiently allocate the available capacity and coordinate the flexible demand of electric vehicles on a local level [1]. Furthermore, EVs can only contribute to a carbon free mobility when their demand is satisfied by renewable energy sources (RES) [2].

1.1 Research Objectives and Contributions

In order to address the requirements mentioned above our research objectives are to 1) Develop a decentral, swarm based coordination approach to utilize EV demand flexibility from private end customers; 2) Centrally optimize charging management of EV-fleets while accounting for spontaneous booking requirements in the fleet; 3) Integrate local generation and supply equipment (e.g. microgrids) in the charging coordination mechanisms; 4) Evaluate the economic potential of EV demand flexibility in different application cases, in particular for grid support; 5) Define a design for an IT Service platform for EVs and finally 6) provide requirements and a preliminary market design to enable the marketing of demand side flexibility in a cellular grid context.

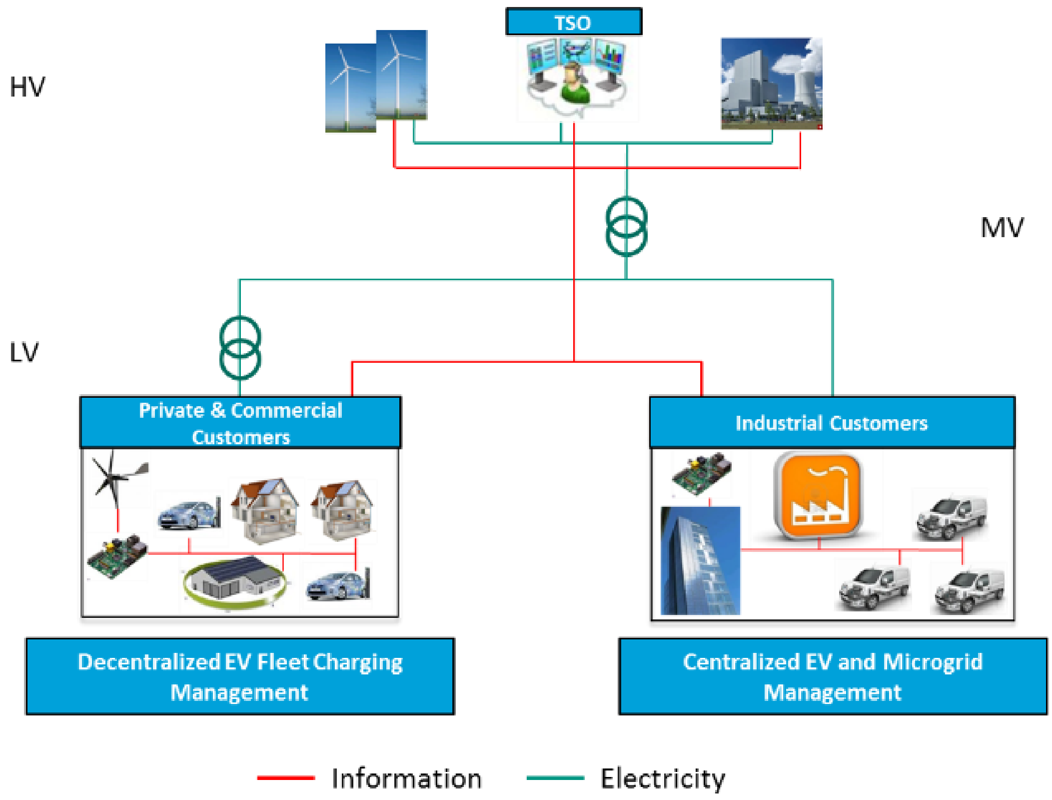

Figure 1Figure 1: Research Scenario of the IMEI Project

2 Decentral Charging Management

We develop a decentral or swarm based charging management heuristics in order to enable an information efficient and privacy preserving charging coordination mechanism for a local setting. We implement an exemplary scenario with 400 EVs and the corresponding houses of end consumers in one grid area. We then set the objective to maximize the usage of RES in the area while transformer capacity limits are respected. We implement the setting using real life mobility and generation data from Germany. The results show that as compared to the centralized optimal schedule, the decentral swarm heuristic can achieve 98,6% of the optimal value w.r.t. the utilized renewable energy for EV charging. At the same time it can increase the utilization of local RES by 25,5% as compared to no coordination in the same setting.

To realise the swarm based approach different architectures were developed. All of them consisted of an observer/controller system on the intra agent side.

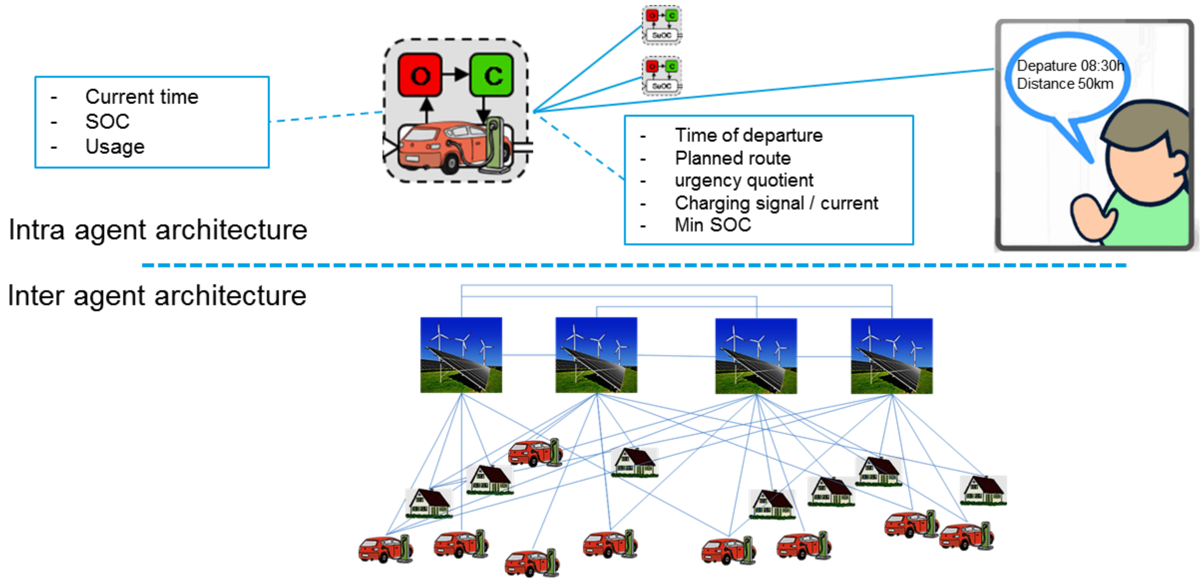

Figure 2: Intra/Inter Agent Architecture

The evaluated architectures differntiated of the the inter agent architecture where three different approaches were tested.

The Base Model:

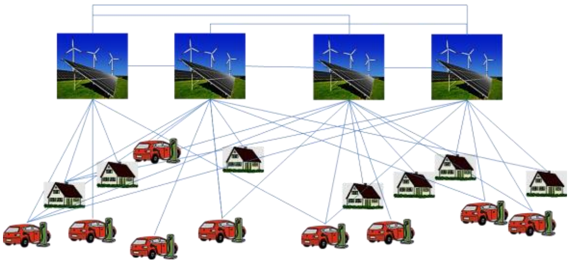

Figure 3: Base Model Inter Agent Architecture

AHK (hierarchical communication)

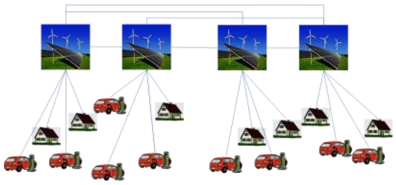

Figure 4: AHK Inter Agent Architecture

ADP (disjoint pools)

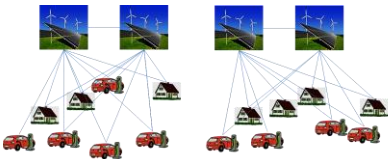

Figure 5: ADP Inter Agent Architecture

Models in comparison:

Charging variant	Usage of renewables	Max power	VK
uncoordinated	63,04 %	1494 (604) kW	0
fastest	63,48 %	584 kW	0
As late as possible	61,84 %	1169 (559) kW	0

Base Model	79,16 %	331 kW	1005
AHK	78,68 %	428 kW	116
ADP	69,91 %	465 kW	105

Table 1: Models in comparison

The evaluation of the models showed, that the Base Model was the most effective model regarding the usage of renewable energies and had the lowest peak power load.

The mechanism was evaluated in different scenarios and has been integrated in the IT Services Platform and applications that are sketched in the next paragraphs. To do so, am others the ISO 15118 and OCPP protocols were used and complemented by project specific extensions.

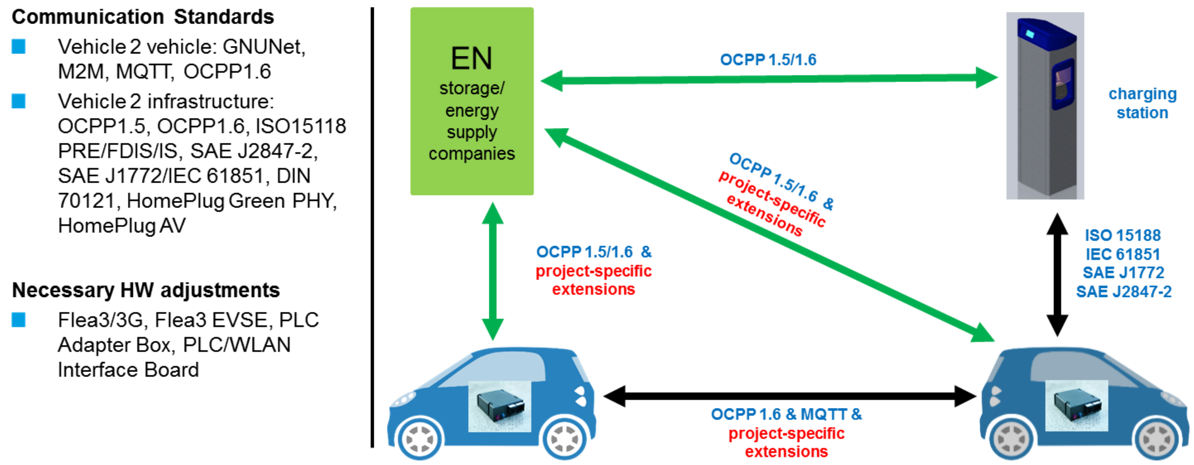

Figure 6: Communication Architecture

3 Central EV-Fleet Charging Management

Topics to be considered in the area of central EV-fleet management are optimized operating strategy for fleets and include, among other things, aspects of battery life, spontaneous booking, intermodality and the rapid charging. Furthermore, questions concerning services and interfaces to external services are addressed. Another topic of this part of the project, was the integration of the EV fleet into the local smart grid, thus enabling the fleet operator to optimize the usage of renewable energies while ensuring the EV fleet is always usable by its users. On top of this, an optimized distribution of energy and the building shall be achieved by the models developed in this work package. The results of this work package have been integrated in a software demonstrator. The Basis of these simulations, was the following model of, for example a small company, with its own means the generate energy from renewable resources (600 kW), a stationary battery storage (800kW / 1 MWh), a standard grid connection (700 kW) and a fleet of EVs:

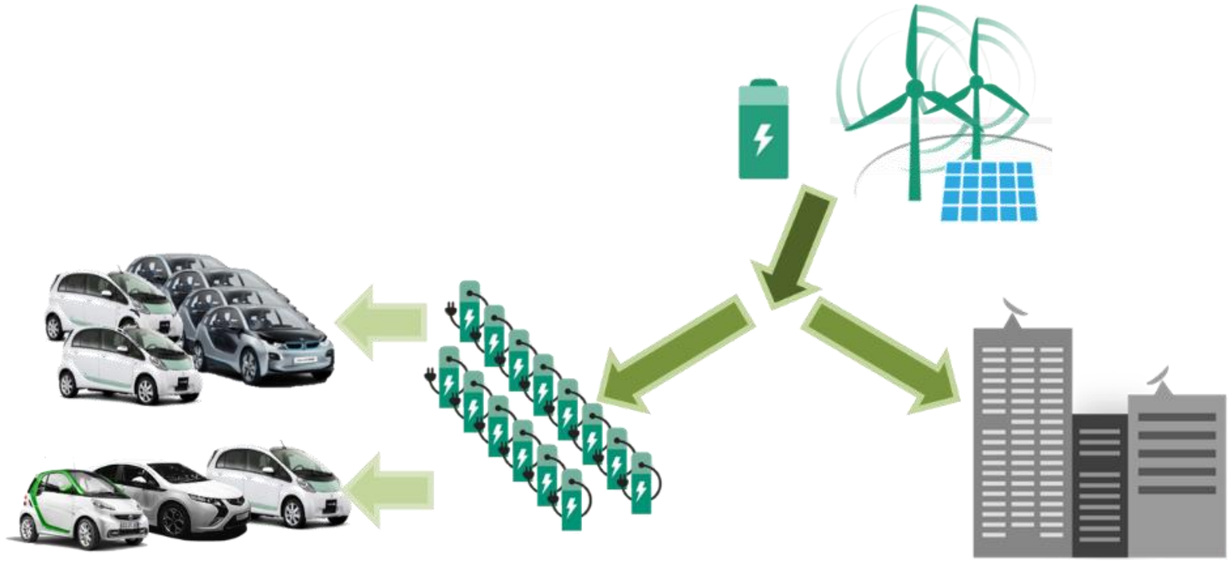

Figure 7: Scenario of the central EV-fleet management model

With this setup the following algorithms were developed and tested:

algorithm	**Provider-Limit**	**PV usage**	**Battery storage**	**Load transfer**	**Load balancing**	**description**
NonBalanced						Instant charging until BSOC 100%
ChargeLate				X		Charging just before departure
Limit	X					Prevention of overload
DynLa	X	X		X		Maximization of usage of renewables
NightBalanced	X	X	X	X	X	Charging as cheap as possible while using renewables

Table 2: Central Fleet Management Algorithms

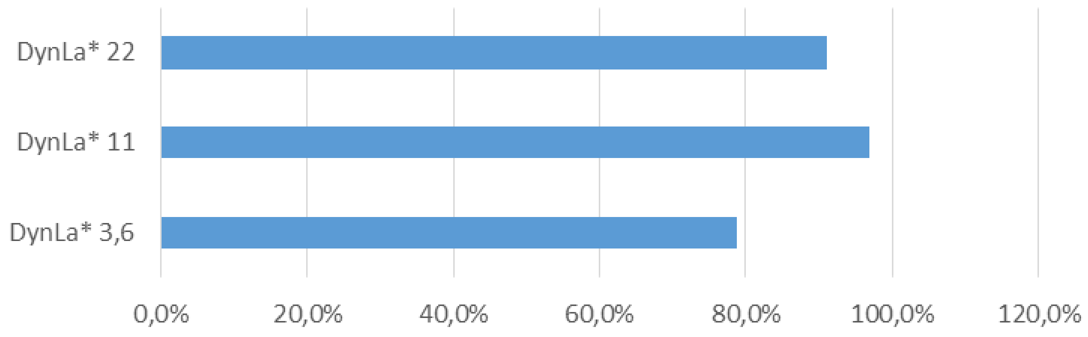

Figure 8: Possible EV Bookings using the DynLa Algorithm

In Figure 8 three different variants of the DynLa Algorithm are show, using 3,6, 11 or 22 kW each to charge the EV fleet. In our real life test, over 9.200 bookings of fleet cars have been performed and with the DynLa*11 algorithm even today almost all bookings would have been possible with an EV.

On top of this up to 70% of the needed energy could have been provided by the photovoltaic power plant in the scenario as shown in Figure 9:

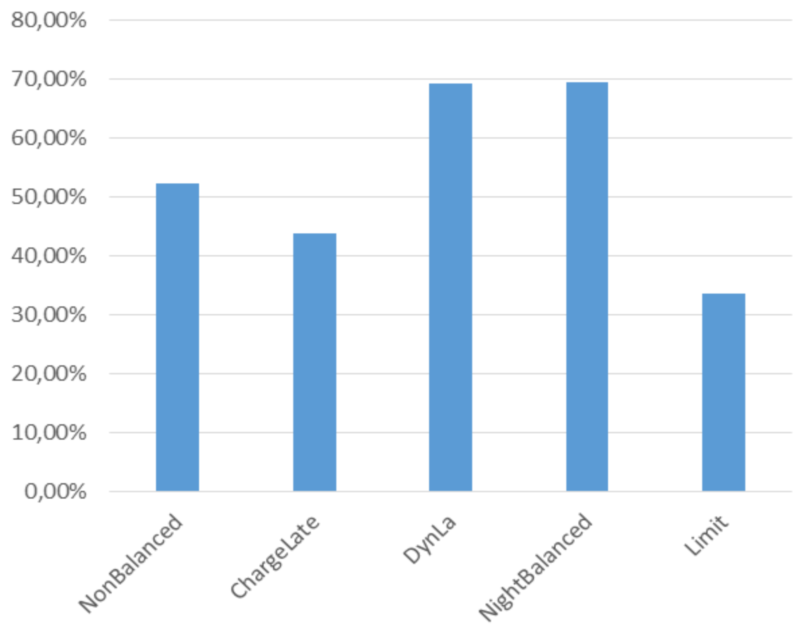

Figure 9: share of photovoltaic energy

4 IT Services for Integrated EV Systems

Potential IT services are designed for users of EV fleets. To this end, the general requirements for an IT service for EV fleets are defined first and foremost. On the basis of results from the project "eFlotte". The general requirements for an IT service for EV fleets will then be incorporated into the design of potential IT services. A potential IT service would be "InCarAdvertising", for example. After designing potential IT services, the IT services are examined for indirect network effects of multi-sighted markets and their impact on the services platform. A prototypic implementation of the IT services in the SAP billing system has been realised until the end of the project. During the project the following applications has shown to be the most promising:

- Advertising the vehicle by route
- Personalization via customer profile
- Display of restaurants and/or shops on the route
- Combination with discount vouchers

These applications could be integrated in the navigations systems of the EVs or even into the head-up displays:

Figure 10: Possible Integration of value added services into an EV

The first step to implement these applications was to gather user data, to know which vouchers, for example, would be the most fitting. This was done by an applications which generated added value in its own for the user as it could be used to find charging station which suited the user's preferences.

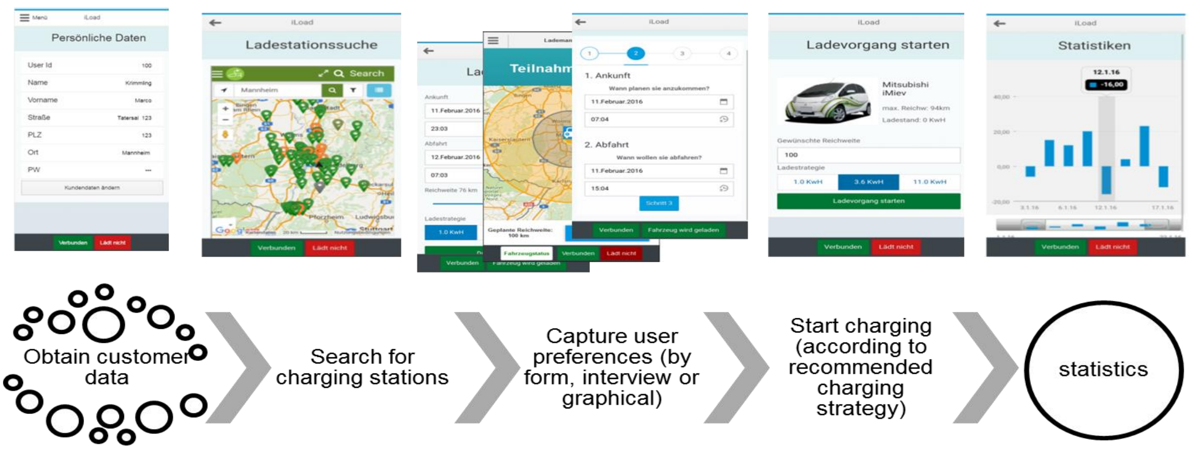

Figure 11: IMEI App

5 Cyber-Physical Layers for Marketing of Future Demand Side Flexibility

In the last work package it is intended to provide answers on which business models will be able to emerge in the field Smart Mobility – Electro mobility - Smart Grid. In the first step, a Meta study is conducted. Relevant studies from both Germany, but also from other European countries and other regions worldwide relevant to the Baden-Württemberg industry are used for this purpose. Based on these results and the current business models, a GAP analysis is then prepared, which, together with the derived megatrends, forms the basis for the following work packages. A market design for cities and municipalities is designed as conceptual work in the form of an IT architecture of a cyber-physical layer.

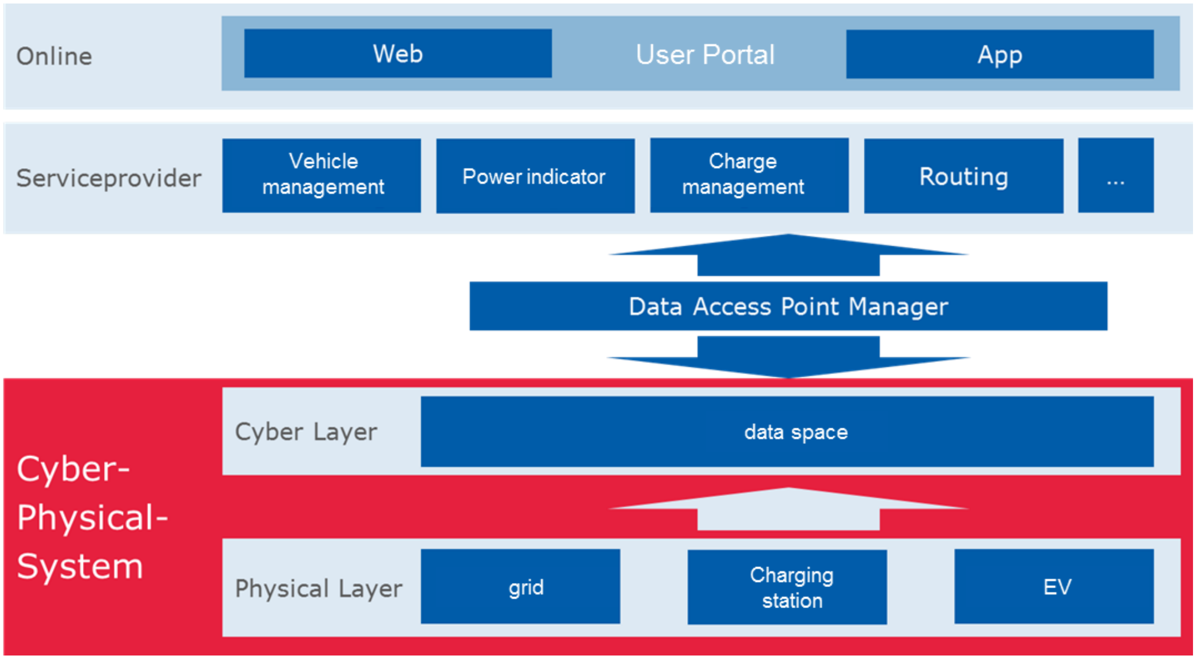

Figure 12: Cyber-Physical-System with a Data Access Point Manager

In addition, a process consideration of the essential processes is carried out in such a potentially self-sufficient network area. Particular attention is given here to a realistic view of the cellular approach in the form of an evaluation. A concept for the provision and billing of flexibility in a cellular network is developed. This is also done against the background of the analyses carried out in the first step of this work package. From these findings, future market designs will be developed that will enable the project partners and, in addition, the Baden-Württemberg location to successfully operate in the future mobility and energy markets.

Acknowledgments

This research was funded by the German Ministry of Research and Education (BMBF) under grant number 16EM00054. The authors are grateful for the support.

References

[1] Flath, C. M., Ilg, J. P., Gottwalt, S., Schmeck, H., & Weinhardt, C. (2013). Improving Electric Vehicle Charging Coordination Through Area Pricing. Transportation Science, 1–29.

[2] Schuller, A., Flath, C.M. & Gottwalt, S., (2015) Quantifying load flexibility of electric vehicles for renewable energy integration. Applied Energy, 151, pp.335–344. Available at: http://www.sciencedirect.com/science/article/pii/S0306261915004432.

Author

Sven Lierzer was born on June 2nd 1982. Following his studies of political science and sociology at the University of Tubingen, he started to work at BridgingIT GmbH.

In the last five years he has been engaged in issues of several industries mainly utilities. He worked on innovations such as Smart Grids, new mobility concepts e.g. electric mobility and smart cities, both on national and international level. At this, Sven Lierzer advises large companies and corporations as well as governmental organizations on aligning their strategy.

Sven Lierzer is a member of several expert circles including:

- *Representative of BridgingIT GmbH at the BEM e.V. and the Smart Grids BW e.V.*
- *Project manager and electric mobility expert in the leading edge cluster Electric Mobility South-West projects SGI and IMEI*
- *Expert at the parallel research into effectivity within the German federal program "Electric mobility Showcase"*
- *and author/co-author of various publications plus expert in various special topics as:*
    - *Research program "Horizon 2020" of the European Union*
    - *Electric Mobility E-Roaming, Smart Charging and Smart Grid*

Within the scope of innovation and business development Sven Lierzer is engaged with the current trend topic of Digitization – from Big Data, Industry 4.0 and demographic change through to issues of the whole transformation of industries.