Grant number: 769016
Project duration: Sept 2018 - Feb 2022
Project Coordinator: Jacqueline Floch, SINTEF

HORIZON 2020: Mobility for Growth
MG-4.2-2017
Supporting Smart Electric Mobility in Cities
Project Type: Innovation Action

greencharge2020.eu

GreenCharge Project Deliverable: D2.15

Final Report for Bremen pilot: Lessons Learned and Guidelines

Authors: Bernd Günther (Ed.), Andi Dittrich, Markus Spiekermann (PMC eG)
Dennis Look, Paal Myhre (ZET GmbH)
Beate Lange, Michael Glotz-Richter (City of Bremen)

www.civitas.eu

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016

Grant number: 769016
Project duration: Sept 2018 - Feb 2022
Project Coordinator: Jacqueline Floch, SINTEF

HORIZON 2020: Mobility for Growth
MG-4.2-2017
Supporting Smart Electric Mobility in Cities
Project Type: Innovation Action

About GreenCharge

GreenCharge takes us a few important steps closer to achieving one of the dreams of modern cities: a zero-emission transport system based on electric vehicles running on green energy, with traffic jams and parking problems becoming things of the past. The project promotes:

Power to the people!	The GreenCharge dream can only be achieved if people feel confident that they can access charging infrastructure as and when they need it. So GreenCharge is developing a smart charging system that lets people book charging in advance, so that they can easily access the power they need.
The delicate balance of power	If lots of people try to charge their vehicles around the same time (e.g. on returning home from work), public electricity suppliers may struggle to cope with the peaks in demand. So we are developing software for automatic energy management in local areas to balance demand with available supplies. This balancing act combines public supplies and locally produced reusable energy, using local storage as a buffer and staggering the times at which vehicles get charged.
Getting the financial incentives right	Electric motors may make the wheels go round, but money makes the world go round. So we are devising and testing business models that encourage use of electric vehicles and sharing of energy resources, allowing all those involved to cooperate in an economically viable way.
Showing how it works in practice	GreenCharge is testing all of these innovations in practical trials in Barcelona, Bremen and Oslo. Together, these trials cover a wide variety of factors: *vehicle type* (scooters, cars, buses), *ownership model* (private, shared individual use, public transport), *charging locations* (private residences, workplaces, public spaces, transport hubs), energy *management* (using solar power, load balancing at one charging station or within a neighbourhood, battery swapping), and *charging support* (booking, priority charging).

To help cities and municipalities make the transition to zero emission/sustainable mobility, the project is producing three main sets of results: (1) *innovative business models*; (2) *technological support;* and (3) *guidelines* for cost efficient and successful deployment and operation of charging infrastructure for Electric Vehicles (EVs).

The *innovative business models* are inspired by ideas from the sharing economy, meaning they will show how to use and share the excess capacity of private renewable energy sources (RES), private charging facilities and the batteries of parked EVs in ways that benefit all involved, financially and otherwise.

The *technological support* will coordinate the power demand of charging with other local demand and local RES, leveraging load flexibility and storage capacity of local stationary batteries and parked EVs. It will also provide user friendly charge planning, booking and billing services for EV users. This will reduce the need for grid investments, address range/charge anxiety and enable sharing of already existing charging facilities for EV fleets.

The guidelines will integrate the experience from the trials and simulations and provide advice on localisation of charging points, grid investment reductions, and policy and public communication measures for accelerating uptake of electromobility.

For more information

Project Coordinator: Jacqueline Floch, Jacqueline.Floch@sintef.no

Dissemination Manager: Reinhard Scholten, reinhard.scholten@egen.green

Executive Summary

In this deliverable the main findings and conclusions are described for the Bremen pilot. This pilot comprises two demonstrators dealing (a) with charging commuter-EVs supported by green energy supply from PV system and a buffer storage and (b) eCarSharing introduced in a new housing neighbourhood. Both topics are related with the Bremen SUMP strategy, wherein the demonstrator results are to be included.

Starting from the relevant GreenCharge objectives in section 2, it is briefly described, how these objectives were achieved for both demonstrators. The results based on the DoA are listed in terms of the 3 categories, i.e., the Evaluation results/lessons learned (R-ELL), the Technology Prototypes (R_TP), and the Business Models (R_BM).

In section 3 the two demonstrators are outlined separately focusing on the technologies that have been developed in GreenCharge both as hardware and software components.

Section 4 is dealing with the measures implemented in the pilot together with the KPIs relevant for the demos.

The data collection process running in manual and automatic mode is described in section 5. Some major issues resulted from the low user number due to the pandemic situation and obligatory home office work, but also from extremely low numbers of users in eCarSharing. Respective obstacles and measures to overcome these issues are described in some more detail.

Finally, from the results and experiences guidelines are suggested regarding further work on the above topic and recommendations are given on how to further develop the implemented GreenCharge solutions and how to include the results in Bremen's SUMP strategy.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

Table of Contents

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

Table of Figures

List of Tables

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
API	Application Programming Interface
CMS	Charge Management System
CP	Charge Point
CPO	Charge Point Operator
CS	Charging Station (usually comprising a multitude of CPs)
EV	Electric Vehicle
Git	Distributed Version Control System (working for Unix/Linux and MS-Windows environment)
HW (h/w	Hardware
ICE	Internal Combustion Engine (in cars)
KPI	Key Performance Indicator (used here to quantify the impact of a measure)
LDAP	Lightweight Directory Access Protocol (protocol used for authentication, authorisation, user lists)
OBD	On-Board-Diagnostics
OCPP	Open Charge Point Protocol (OCPP 1.6 is current standard for backend communication)
OCR	Optical Character Recognition (s/w for text recognition in images)
OEM	Original Equipment Manufacturer
RES	Renewable Energy Source
SW (s/w)	Software
SUMP	Sustainable Urban Mobility Plan
UUID	Universally Unique IDentifier

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

List of Definitions

Table 2: List of definitions

Definition	Explanation
API	The Application Programming Interface is a set of clearly defined methods of communication among various compounds
Gateway	Joins two networks so the device on one network can communicate with the device on another network
KPI	Key Performance Indicator used to quantify the impact of a Measure (see below).
Measure	A measure is a mobility or charging related action implemented by a city or other stakeholders, e.g., the implementation of a new infrastructure, the provision of a new service, a new organisation of the travel to work, or activities to change awareness, acceptance or attitude and behaviour of citizens or visitors. The extent to which a measure succeeds in achieving its objective is assessed using KPIs (see above)
OTA-key	OTA-key (Over-The-Air) is an in-car component that accepts via Bluetooth communication the user's ID to activate the central door locking. It usually comes as a small box connected to the EVs OBD-port.
Photovoltaic	Photovoltaic panels convert light energy into electric energy using semiconducting materials
Scenario	A scenario describes a specific of a proposed system by illustrating some interaction with the proposed system as viewed from the outside, e.g., by a user, using sand evaluation principles.pecific examples. In GreenCharge, a scenario is a higher level of description of the system and can be modelled using one or several use cases.
State-of-Charge (SoC)	The state of charge (SoC) is an indication of the amount of energy stored in a battery. It is given as a percentage, meaning the percentage of the full capacity currently available in the battery. This is not identical to the nominal (starting) capacity. The SoC is difficult to measure accurately, but several methods are available to give approximate value at least, and most EVs have the SoC displayed on the dashboard. The SoC is usually not accessible via in-car components, e.g., the OBD interface.
SUMP	A SUMP is a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation,
Use case	A use case describes how a system will be used and is a tool for modelling requirements of a system. In GreenCharge, a scenario is a higher level of description of the system and can be modelled using one or several use cases.
YAML	Human-readable data serialization standard that can be used in conjunction with all programming languages and is often used to write configuration files.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

1 About this Deliverable

1.1 Why would I want to read this deliverable?

This document describes the lessons learnt from implementing the Bremen pilot in the GreenCharge project. The Bremen pilot considers situations typically found in all major cities: Company sites located in the outer regions of the cities, where many employees are commuting from surrounding regions. In the central part of cities too many private cars are occupying public space, making CarSharing a viable option to many inhabitants with respect to their mobility needs, but needs to be combined with public transport.

Therefore this document contains lessons learnt from (A) giving commuting employees the chance to recharge their EVs using renewable energy on their employer's site, and (B) having an eCarSharing option for a residential neighbourhood implemented within a multi-modal mobility approach.

1.2 Intended readership/users

Expected readers of the Final Report for the Bremen pilot are primarily those, who plan to replicate solutions that were found to be advantageous in the context of reducing number of cars in the city center via car-sharing, and supporting companies to foster smart charging from on-site PV, i.e.,

- Housing cooperatives
- Municipal authorities
- Charge point operators (CPOs)
- Car-Sharing providers
- Electric Mobility Providers (EMPs)
- Companies owning on-site PV.

1.3 Other project deliverables that may be of interest

The following public project deliverables might be useful for the reader to get a more comprehensive view on the conditions and relationship of the Bremen pilot:

- D2.9 *Description of Bremen Pilot and User Needs* - document describing the Bremen pilot in terms of challenges, user needs, use cases, scenarios, stakeholders and involved locations and the baseline (current situation).
- D2.10 *Implementation Plan for Bremen Pilot* - document describing the planning of the tests to be carried out at the pilot site. It includes scenarios to be demonstrated, time schedules, stakeholders and locations selected, users selected for workshops and for testing, hardware and software to be installed, tests to be run and data to be collected, etc.
- D2.11 *Pilot Component Preparation for Full-Scale Pilot (Bremen)* - deliverable describing the deployment and the testing of software and hardware components to be used in the pilot, to prepare for the full-scale pilot implementation.
- D2.12 *Full-Scale Pilot Implementation* - document describing the implementation of the Bremen pilot. This includes the specifics of the hardware and software components used in the Bremen pilot. The deliverable D2.12 itself <u>is</u> the Bremen pilot.
- D2.13 *Technical Monitoring Report and Feedbacks (Bremen)* - deliverable presenting the intermediate results from the Bremen Pilot with its 2 demonstrators.
- D2.14 *Intermodal On-street Car-Sharing Stations in a New Housing Development.*

This deliverable (D2.15) describes lessons learned from the Bremen pilot. The lessons learned from the two other pilots in GreenCharge are described in:

- D2.8 *Final Report for Oslo pilot: Lessons Learned and Guidelines*
- D2.21 *Final Report for Barcelona Pilot: Lessons Learned and Guidelines*

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

2 Objectives

2.1 How were the objectives achieved?

The general GreenCharge Objectives, as they were defined in the DoA, are listed below. This section will describe how they were achieved in the Bremen pilot, which consists of 2 demonstrators: BRE.D1 (charge@work) and BRE.D2 (eCarSharing).

The following table shows how the objectives (O1-O5) were addressed in the Bremen pilot (based on Part B – Project Description):

Table 3: Objectives addressed by Bremen pilot

Objective	How the objectives were addressed	
	BRE.D1	BRE.D2
(O1) Prototype and test business models to support viable business cases for EV charging for urban and sub-urban areas with renewable energy in various contexts		Development and improvement of eCarSharing service demonstrated in a local neighbourhood. Concept and feasibility analysis of sharing Charging points intended for CarSharing EVs with owners of private EVs during off-time slots
(O2) Demonstrate booking services for charging providing EV users predictable access to charging services underway		
(O3) Demonstrate services for optimised utilisation of existing grid capacities and local RES by implementing coordinated load shifting in neighbourhoods and private ground leveraging available local storage	Charging requested by user via frontend web-APP is optimised by an energy mgmt. solution that couples PV, battery and request from CPs	
(O4) Demonstrate services for management of storage of energy to remedy EV charging in situations with high peak load	Charging of commuters' EVs and fleet EVs is managed by s/w backend in a way to allow power peak shaving of the local grid	
(O5) Recommend solutions and provide guidelines as a planning tool for successful deployment of EV charging infrastructures. The guidelines will be tailored to use in SUMP processes	Recommendations and lessons learnt from the pilot were given to WP7 and WP8	Recommendations and information on lessons learnt from the pilot were given to WP7 and WP8. Neighbourhood residents are kept informed about CarSharing options

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

Specific objectives for the Bremen pilot are to address:

• How to combine and in practical situations **operate stationary energy storage facilities** (batteries) and **on-site volatile (PV) energy supply** with the needs of charging electric vehicles in an eCarSharing situation as a major contribution to the "Energiewende" issue;

• How to **integrate and run a low-cost battery-based charging solution** on existing company parking-lots by using 2nd-life (used) EV-batteries;

• How a **fleet management platform for EV's can be combined with booking of charging facilities** in a user-friendly way in order to (a) enhance the reliability of recharging options and (b) optimize the charging process with respect to cost and use of green energy;

• How to **promote public-owned intermodal EV-car-sharing stations** like, e.g., "mobilpunkt" (= mobility point) stations (specialty in Bremen pilot) with re-charging options in such a way that people are encouraged to use eCarSharing thus relieving the city dramatically from parked cars (SUMP element);

• How to **integrate eCar-Sharing in new housing developments** – as a core element of a wider mobility management to reduce the number of private cars in urban environment (SUMP element).

All these objectives were followed throughout the project period. In the following 2 headers it is described, how these objectives were addressed in the 2 Bremen demos.

2.1.1 BRE.D1 - Charge@work

Objective O3 deals with the use of local RES and the use of stationary energy storage for cost-efficient charging. For this purpose, a technology prototype was set-up comprising two - already existing – solar carports on private entity ground. One of these was extended by 2 CPs for GreenCharge purpose and coupled to a system of decommissioned EV batteries totalling a nominal capacity of 54kWh. The other one was coupled to a Redox-Flow battery (RFB) with a nominal capacity of 100 kWh. A proprietary s/w backend solution was designed and integrated. The CPs could be booked by registered users (CPs not publicly accessible) only, i.e., commuters who were interested in charging during their working hours. For the system to plan charging, via a web-based frontend some manual input data are required from the user, i.e., current SoC, energy demand, estimated departure time, and urgency level. The energy management then meets the requirement considering the boundary condition not to exceed a maximum power limit on the local grid.

Objective O4 deals with the issue of peak loads that must be prevented by limiting power given to the CPs from the grid. This requirement can be met by load shifting and the additional use of PV energy and the energy storage. Slow recharge of the stationary battery overnight, when there are no commuters charging, keeps maximum load on the grid confined and prevents expensive peak power situations. The use of decommissioned EV batteries was intended because a recycling market for such systems is foreseen during this decade.

2.1.2 BRE.D2 – eCarSharing

The BRE.D2 demonstrator illustrates how electric vehicles can be integrated into a neighbourhood as part of a mobility management.

The use of EVs for the provision of a car sharing service poses particular challenges, especially with regard to the provision of recharging facilities. Technical systems must adapt to the specific requirements in order to provide users with the best possible service. At the same time, however, due to the low margins in car sharing, the economic efficiency of the systems must be considered. The purchase of EV alone exceeds the purchase costs of ICE vehicles by far. In order to improve the business case of eCarSharing and to enable innovative additions to the service, it was necessary to replace the system used until the start of the GreenCharge Project by a new system. This new system consists of a new developed fleet management system as a backbone of the service, as well as a new CarSharing app named “ZET.Share”, which is available on iOS and Android.

As parts of a comprehensive district-based mobility management system, the following three sub-goals have been examined with regard to their feasibility:

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

1. How can eCarSharing be implemented in the context of new housing developments?

An integrated eCar-Sharing solution provides several positive contributions to the development of a district at the same time. It reduces the proportion of private vehicles required, it reduces the need to create parking space and it reduces local emissions through the exclusive use of EVs.
For demonstrator BRE.D2 two eCar-Sharing stations have been set up in close cooperation with local housing cooperatives.

2. How can a fleet mgmt. be combined with booking of charging facilities for private EV owners?

In addition to the goal of reducing the share of private vehicles through the implementation of car sharing, it was also investigated to what extent the charging points created could serve to provide more charging options for private EV users and thus accelerate the switch from vehicles with internal combustion engines to purely electric vehicles in the local neighbourhood. Such a system would also have contributed to objective O1.

It was found that a new developed fleet management system for carsharing is a key requirement for such a solution. The fleet management system had to be flexible enough to be connected to different 3rd Party Services in a financially reasonable way. As a result, the so called "ZET.Share" system have been developed, tested and improved during the project.

In addition, an approach for sharing the charging infrastructure was developed, which for various reasons could be presented just as a concept only. The main reasons for this were the limited budget, lack of standards, low utilization of the vehicle fleet, and low impact on the business case.

3. How can intermodal EV-car-sharing stations be promoted?

Since e-car sharing in particular can only be operated profitably if enough customers use the vehicles, further ways were sought to increase the use of shared vehicles. The idea of intermodal EV-car-sharing stations promised to not only increase the potential catchment area around the stations but also to increases the chances of getting people to change their mobility behaviour.

In the run-up to the project, there was coordination with the local public transport system with regard to the creation of a multimodal mobility platform. Since the public transport system did not want to provide a technical interface for booking bus and train tickets via the ZET.Share system, it was agreed that the ZET service could potentially be integrated into the planned "Fahrplaner"-system. However, the market introduction of the system was delayed on the part of the public transport operator, so that integration could not be demonstrated during the project period.

Alternatively, the connection of the CarSharing system to a Mobility as a Service platform was prototyped, which was developed during the eMaaS project by ZET Austria.

2.2 Results based on the DoA

In the project description (DoA) of GreenCharge, the project's main results are separated into five topics. The Bremen pilot contributes to three of these topics:

- (R_ELL) Evaluation results and Lessons Learned
- (R_TP) Technology Prototypes
- (R_BM) Business Models

The results within each topic are further detailed in the following 3 sub-sections.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

2.2.1 (R_ELL) Evaluation results and Lessons Learned

One of the project's main results is *Evaluation results and Lessons Learned* (denoted R_ELL). This result shall contribute to all the project's objectives. To provide learning from the piloting activities the DoA (section 1.3.1) defines seven innovation scenarios. In the Bremen pilot, 2 of these innovation scenarios were physically implemented and demonstrated:

Innovation scenario	Results from BRE.D1	Results from BRE.D2	Contribution to objectives
Scenario 1: Charge planning and booking	• Web-App developed, which gives availability of CPs, accepts user's charge demand, time frame, and degree of priority • s/w backend developed with EMS integrated		*(O4) Demonstrate services for management of storage of energy to remedy EV charging in situations with high peak load;* *(O5) Recommend solutions and provide guidelines as a planning tool for successful deployment of EV charging infrastructures.*
Scenario 7: E-Mobility in innovative 'mobility as a service'(MaaS)		• eCarSharing App shows live state of charge (SoC) before booking • eCarSharing App shows range estimate • SoC monitored by fleet mgmt. system • EV Information can be shared with 3rd party MaaS system	*(O1) Prototype and test business models to support viable business cases for EV charging for urban and sub-urban areas with renewable energy in various contexts;* *(O5) Recommend solutions and provide guidelines as a planning tool for successful deployment of EV charging infrastructures.*

2.2.2 (R_TP) Technology Prototypes

The hardware and software deployed in the demonstrators are described in the following deliverables:

- *D2.11 Pilot Component Preparation for Full-Scale Pilot (Bremen)* - this deliverable describes the deployment and the testing of software and hardware components to be used in the pilot, to prepare for the full-scale pilot implementation.
- *D2.12 Full-Scale Pilot Implementation for Car Sharing* - this document describes the implementation of the Bremen pilot. This includes the specifics of the hardware and software components integrated and used in the Bremen pilot.

A summary of the deployed hardware and software is shown in Table 4 in section 3.1.3.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

2.2.3 (R_BM) Business Models

The business model developed for BRE.D2 is illustrated in Figure 1. For this demonstrator, ZET as the orchestrator provides an eCarSharing service to residents and visitors of a local neighborhood. For this service, ZET bundles the following key elements and assets:

- Operation of the charging infrastructure
- Operation of the shared EVs
- Operation of the user interface (CS-frontend)
- Operation of the fleet management system
- The demonstrated service is based on the connection to the local housing corporation which, in addition to the active sharing of the vehicles, resulted in new sources of income: Compensation payment for the suspended creation of parking space.
- Marketing Cooperation

The residents of the housing corporation receive the following discounted services in return:

- Low cost shared EVs
- Free charging of the vehicles regardless of the charge level when returning the vehicle
- Free charging of the vehicles during an ongoing booking at the station

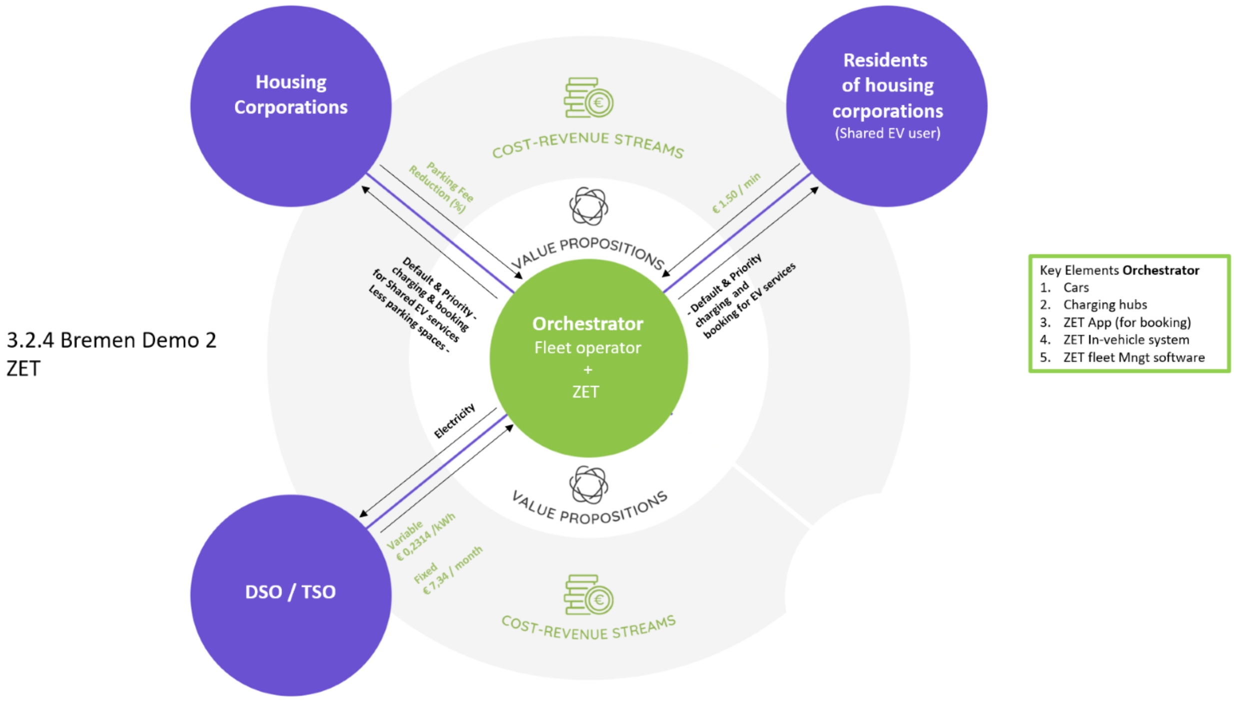


Figure 1: Business Model in BRE.D2

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

3 Operation of the Bremen Pilot

3.1 Description of the demonstrators

3.1.1 General description and description of demonstrator sites

The <u>Charge@work demonstrator</u> was developed in the local region of the technology park around the Bremen University. An R&D facility comprised of two PV-supplied EV-carports has been rented and modified technically to meet the GreenCharge objectives. Commuting employees received a recharge option for their private EVs. The important features to be implemented in the project were the following:

- 5 CPs freely accessible for any employee, company fleet EV, and visitor EV
- On-roof PV systems (4,7kWp and 12kWp, respectively)
- Option to install decommissioned EV batteries for EV charging sessions in CS#3
- Redox-Flow Battery (RFB)
- Registered users that may have access to the CPs after login via App.

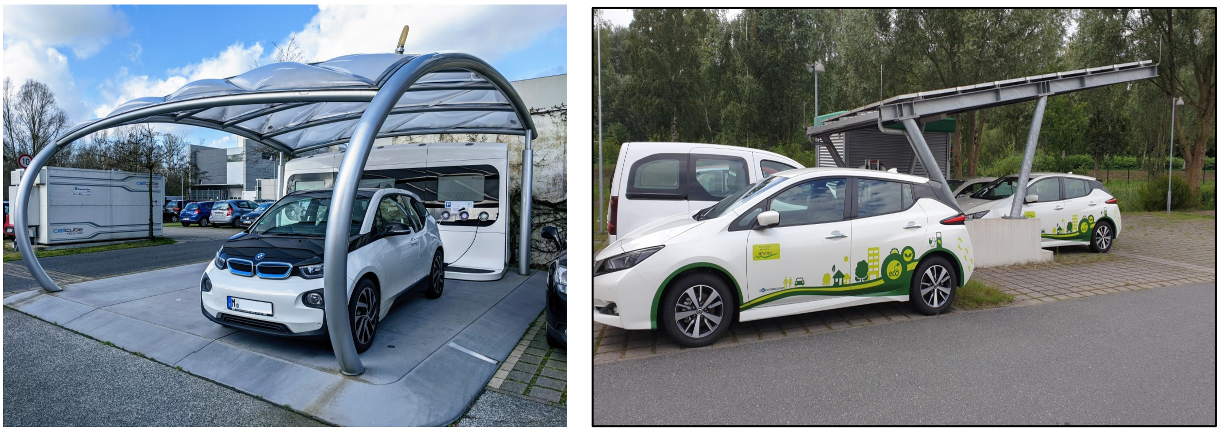


Figure 2: The two charging stations employed in BRE.D1

Figure 1 shows the 2 charging stations of the Charge@Work demonstrator. CS#5 (left) is equipped with the RFB storage, whereas in CS#3 (right) the container in the background is equipped with electricity h/w, e.g., converters and used EV batteries.

The <u>eCarSharing demonstrator</u> operating in a residential neighbourhood is equipped with non-public charging stations and located near stops of public transport (busses). Important features in the baseline situation were the following:

- 4 CP exclusively used for the shared cars
- 4 EV equipped with the OTA Key in-vehicle system
- “ZET.Share” App provided via the app platforms of iOS and Android

A detailed description of the 2 demonstrators D1 and D2 is given in D2.2, D2.9, and D2.10. It should be mentioned that in the course of the project some of the locations had to be changed from the situation at start of the project: For D1 the rental contract for one of the charging stations was not renewed and for D2 two eCarSharing stations were dropped due to low user numbers. Alternate options had been identified and implemented.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

3.1.2 Description of employed hardware and software

BRE.D1 - The h/w and s/w components employed in this demo is best visualized in Figure 3, wherein all components are mentioned that are involved in the charging stations managed by a mutual backend solution. The charging situation before starting the project did not involve any backend control or data acquisition.

The core component of the charging station system is the **gridctrl.aggregator**. It is used as a kind of physical abstraction layer between the h/w components and the backend system. All components on a single charging site are connected to a dedicated gridctrl.aggregator appliance, which provides the backend connectivity for each component as well as local energy routing/load-balancing as part of a larger neighbourhood-EMS.

This unique design pattern eliminates the need for device-specific WAN communication interfaces (UMTS/LTE transceivers, SIM cards) and improves the system reliability including offline operation. Due to its isomorphic architecture it can be run on-site as a stand-alone appliance (high availability and redundancy scenarios; to use non-network enabled components) or virtualized within a compute cloud environment.

The most important s/w component is the **gridctrl.ENCORE** backend, a combined charge-point infrastructure and energy management system owned by one of the stakeholders (Aenon Dynamics - a member company of PMC eG). This component has been adapted for GreenCharge to meet the anonymisation requirements and formatting issues during the demonstration phase.

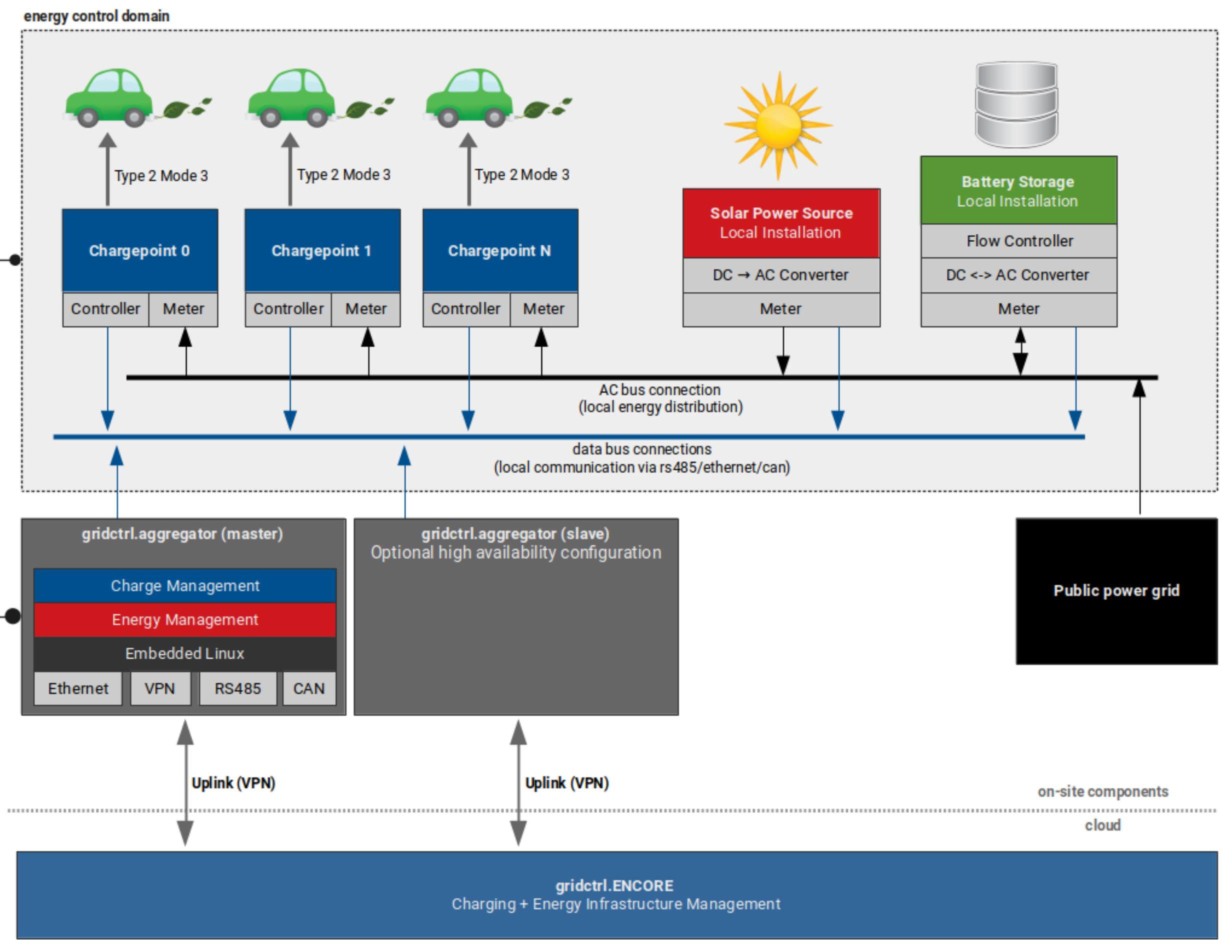


Figure 3: Modular system in GreenCharge@Work demonstrator

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

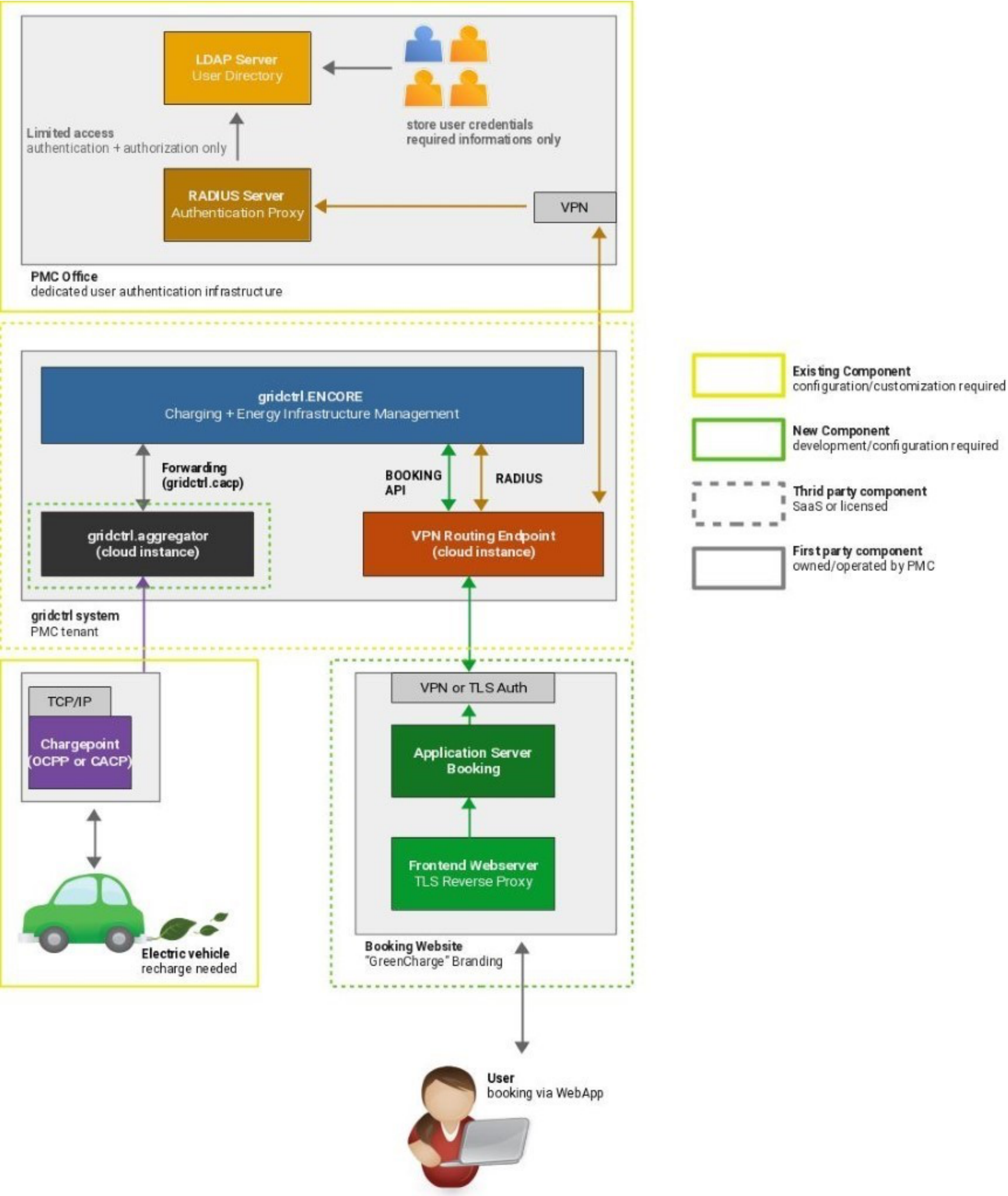


Figure 4: GreenCharge@Work s/w components

Figure 4 visualizes the involved s/w components including the booking system and s/w components that are related to external user and authorization service. A more detailed description of the functionalities of the s/w components related to the charging infrastructure is given in deliverable D4.5 (section 2.3.2).

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

BRE.D2 – This demonstrator consists of a core system supplemented with 2 additions (see figure 4). The core system includes the In-Vehicle-System, the fleet management system and a customer car sharing frontend (CS-Frontend). This core system is supplemented with an interface for different 3rd party services like:

- A Charge Management System
- A Mobility as a Service Platform
- A data management tool

The following h/w-components were integrated into the existing fleet-EVs. **OTA-Keys** provides a s/w-solution intended for keyless opening a pre-booked vehicle for CarSharing. No RFID is needed and no h/w-key. The virtual key is mirrored temporarily via a backend structure onto the user's smartphone and thus contributes to user comfort and CarSharing acceptance.

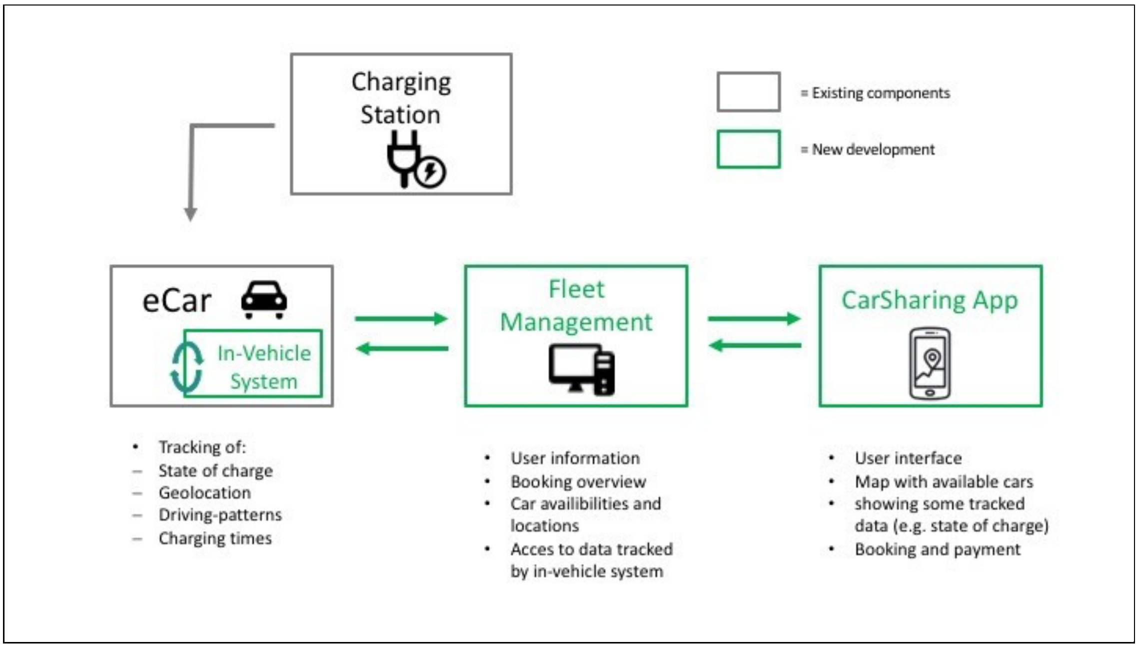


Figure 5: Architecture of demonstrator BRE.D2

3.1.3 Systems developed and/or extended from existing background

For demo 1 the heart of the system, i.e., the gridctrl.aggregator, provides the h/w interface (including embedded s/w) between the charging station system and the charging and energy infrastructure management (gridctrl.ENCORE backend). The backend gridctrl.ENCORE had been extended and adopted to handle all the data needed for the evaluation and convert them into an anonymized format.

For demo 2 all software systems have been developed from scratch to meet the requirements of the GreenCharge project. The in-vehicle system was purchased from Continental, who also provide a software development kit for integration into the software environment.

The following table summarizes the developments done in the two demonstrators during the project period (*Source: D2.12 Full-Scale Pilot Implementation for Car Sharing, Section 2, Table 3):*

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

Table 4: Systems developed and/or extended from existing background

System/ Service	Component name	Type	Before GreenCharge	After GreenCharge	Demo site	Partner
Charge Point Provisioning	Charger CS#3	HW	Plug and Charge	New charger setup capable of processing OCPP1.6 and fully accessible for backend control	BRE.D1	PMC
Charge Service Provisioning	PMC App “GreenCharge”	SW	CPs were activated via RFID card	React-based WebApp used by drivers to book and remotely control a charging session	BRE.D1	PMC
Charge Station Operation	gridctrl.ENCORE	SW	CP without backend control Backend gridctrl.ENCORE available in a basic (proprietary) version	Charging infrastructure software platform providing user authentication and authorization management, charge-point monitoring, and data aggregation from energy meters	BRE.D1	PMC
EV Charging	gridctrl.ENCORE	SW			BRE.D1	PMC
Local Energy Management	gridctrl.aggregator	HW/SW	no energy management (Plug-and-charge)	autonomous network + energy gateway solution to connect on-site-components (e.g., CPs, meters, energy storage) to gridctrl.ENCORE backend via unified communication interface (single link)	BRE.D1	PMC
Roaming*)	Gridctrl.ENCORE with HUBJECT HBS	SW	No roaming option	Roaming provided by Hubject HBS platform (external service)	BRE.D1	PMC
Mobility as a Service	CS-Frontend (ZET APP)	SW	-	The ZET App provides EV access as well as information about public transport to the customer	BRE.D2	ZET
Fleet management	Fleet management system	SW	-	The new Backend system provides EV status information to the fleet manager	BRE.D2	ZET
EV In-vehicle system	OTA Key Box	HW	-	The new installed system plugged to the EV OBD2, allows the communication between EV and other s/w components	BRE.D2	ZET
EV charging	Wall boxes	HW	4 CPs enabling charging for CarSharing EVs at local flats	Charging can be monitored by new developed data collection strategy	BRE.D2	ZET

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

3.2 Operation of the demonstrators

The conceptual idea of the Bremen pilot had referred to the following 4 use cases (covering scenarios 2, 3, 4, and 7 as described in the DoW):

- BRE.1 Enforced booking for priority charging
- BRE.2 Commuter charging at work via PV and 2nd-life battery
- BRE.3 EV CarSharing combined with public transport
- BRE.4 Residential private charging at EV CarSharing station

For all these use cases some adaptions had to be made during implementation of the two demonstrators that will be described below . They are input to an enhanced SUMP strategy.

BRE.D1 - Charge@work

The combination of charging EVs from commuting employees, company (fleet-) EVs, and announced visitors' EVs with their individual charging demands was a challenging task, when adapting the h/w and s/w components listed in Table 4. The EMS had to manage all these demands, while keeping PV usage high, preferred usage of the electricity buffer storage, and respecting the overall peak power limit, and at the same time fulfil the users' charging demands as good as possible.

The backend SW combined to the gridctrl.aggregator was developed from a system that was available from one of PMC's member companies (Aenon-Dynamics GmbH) and was in a rudimentary stage before starting the project. Implementation could be realised as planned and cloud linkage to backend solution worked nearly permanently during the iteration #2 phase (see figure 3). Some problems arose from formatting requirements regarding the acquired research data. Here the csv-format (Excel) was difficult to handle in the context with log-file data. This issue could be removed by developing another data format (YAML-based) for data processing, which could be also used by any other demonstrator in the project.

<u>Use Case 1</u> – Enforced booking for priority charging (BRE.D1)

The basic idea with this use case is to give to a limited number of EVs the option for an immediate recharge. The respective carpool comprises the company (fleet-) EVs as well as the visitors' EVs, since both groups should be transferred into a standby condition as fast as possible. Only for these cars the priority option should apply.

When setting up the demonstrator, the priority option was intended for VIP and visitors only. This turned out not to be appropriate since individual fleet EVs were not allocated to specific users. Therefore, in the demonstration phase, the priority option could be chosen by any user coming to the CPs, since any employee was allowed to use any fleet-EV for business trips. The implementation occurred via the web application, i.e., the user could click the priority option and receives full power from whatever source.

It turned out during the final iteration that some users in their function of "normal" commuters, who charge their private EV, had activated the priority option without being eligible for charging his/her particular car immediately with full power. Such situations can be prevented, e.g., by installing an automatic identification of the EV (EVID) via the CP after cable connection. Alternatively, the vehicle registration number could be detected by a webcam in image mode combined with an OCR s/w controlled via backend automatically. Implementation of such a module would be a future measure employing a couple more constraints, e.g., data protection must not be violated in any case with such a component meaning that the recognition feature for EV registration numbers must be used only to enable the determined button in the web-application (priority option) and data get overwritten directly after.

<u>Use Case 2</u> – Commuter charging at work via PV and 2nd life battery (BRE.D1)

Commuting users charging their private EVs on the company's premises are usually present during office hours, i.e., 6-8 hours typically. Therefore, the demand in electric energy can be met at reduced power level

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

compared to what would be maximal possible at the ac chargers. The power limit restrictions from the local grid can thus be handled easily. In critical situations, when charge demand exceeds the PV and grid capacity, then the additional availability of a buffer storage would relief the grid load. Such a buffer can be recharged overnight at low power (and possibly lower cost).

During the testing phase (iteration #1) the pandemic situation prevented the charge@work demonstrator from having many users, since home office was obligatory for long times. The components, in particular the backend solution, could be tested just with PMC personnel "playing" the user role. In the demonstration phase (iteration #2) the restrictions were partially repealed and thus at least some of the registered users could charge at the demo stations quite frequently. This phase of productive data acquisition occurred basically during the project's extension period. Over 100 charging sessions stemming basically from commuting employees could be monitored. Only few fleet-EVs (with priority option activated) were detected, since the number of business trips with fleet-EVs were at a much reduced level compared to pre-pandemic period.

A major restriction resulted from the fact that the decommissioned EV batteries intended for 2nd-life usage as a stationary buffer storage could not be integrated into the CS#3 system as planned. The HW (5 x 200kg batteries) could be demounted from the EVs. Two of the batteries, summing up to 54 kWh capacity, could be tested successfully with respect to power supply, thermal data, and charging/discharging behaviour. But after integration at the charging station CS#3, all efforts to get access to system's electronic control failed due to missing technical documentation – the OEM supplier does not exist anymore. Therefore, charging demand at this particular station was met by PV- and grid-power only.

BRE.D2 - eCarsharing in a residential neighbourhood

The public EV-Sharing stations KISSINGER and RICARDA-HUCH (see D2.10 *Implementation Plan for the Bremen Pilot*) have been replaced by two other stations ("LESUM PARK" and "EURO") because of the following reasons:

- Due to the negative results of our test and the resulting contractual difficulties, it was no longer possible to continue operating the KISSINGER site in an economic way.
- Giving up the pilot site RICARDA-HUCH resulted from the following considerations: Firstly, the charging infrastructure was managed by the local utility and there was no access to any research data. Secondly, there was a strong "parking pressure" at that station resulting in blockage of our eCarSharing park spaces by parking violators. Thirdly, there were hardly any registered users from the surrounding area, i.e., further investment, e.g., in electric parking brackets, could not be considered as a promising measure.

The CarSharing stations LESUM and EURO were considered much more suitable as pilot sites especially with respect to the demonstration of eCarsharing in residential environments. The LESUM site is located in a new development area in the northwestern districts of Bremen. Within walking distance there are newly built residential units, a well-frequented supermarket, a medical center and a bus stop. Most of ZET's registered users were active in this demonstrator site.

Figure 6: Demonstrator location "LESUM"

The EURO station is located on the newly developed peninsula in the center of Bremen. Newly built apartments were occupied here at the beginning of 2020, and a modern ecosystem of living and working spaces is increasingly being created. This station is also located in the immediate vicinity of a bus stop. Therefore a combination of public transport and car sharing seemed to make sense because of the close proximity.

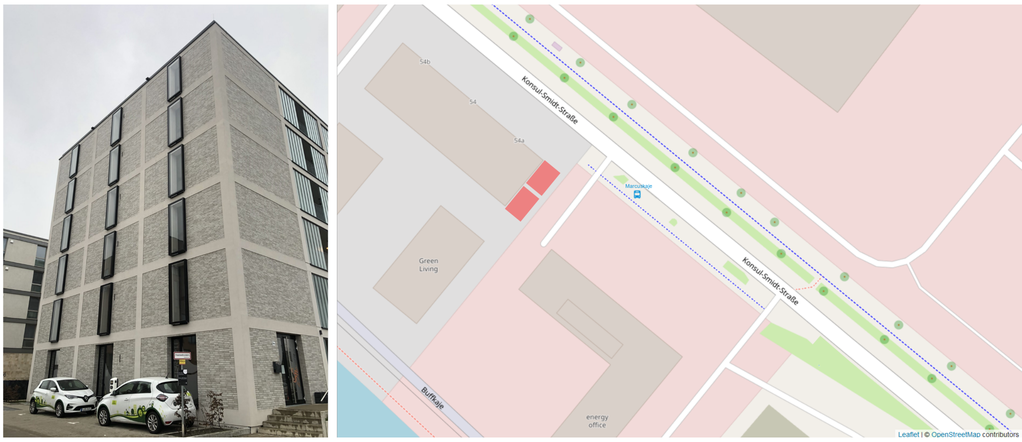


Figure 7: Demonstrator location "EURO"

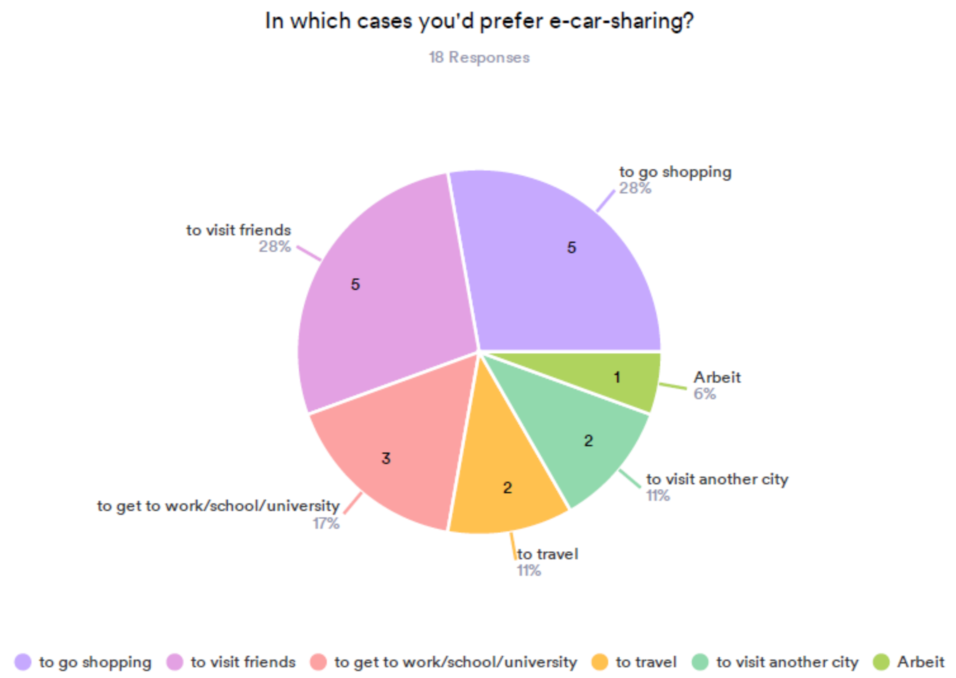
Communication with residents was considered important for both demonstrator sites and was established with the following channels:

- Vehicle branding to generate attention and establish the housing corporative as a point of contact
- Mailing to residents in cooperation with the housing corporative to introduce the offer
- Posters at the stations informing about possibilities to download the app and to get more information
- Webpage to inform users about the service, pricing and the GreenCharge Project.
- Regular distribution of flyers to draw attention to the service and to the survey within the framework of the project.

The central advertising message that was pursued on all communication channels is loosely translated as follows: *ZET.Share - your car sharing in Bremen: Inexpensive, local, modern. Get around the city easily and without emissions.*

As a result, communication with the residents turned out to be difficult. This is reflected on the one hand in the low overall demand, but also in the overall low participation in the survey. At this point, it can only be speculated about the reasons for this, when we assume that some persons, who acted as disseminators in the neighbourhood, could not be convinced. On the other hand, the survey indicated that the COVID-19 pandemic had an important impact on the general need for car-sharing in this particular neighbourhood.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.



According to our data the use of car sharing vehicles decreased since the pandemic and did not resume easily after experiencing less restrictive COVID-19 measures. Our survey has shown that the relevant reasons for using eCarSharing are exactly those that were affected most by the pandemic, i.e, shopping and visiting friends. Thus the low number of users can be explained by the overall lower demand for mobility throughout this period.

Despite the overall low utilization of the EVs, it was still possible to achieve a constant usage of the service. Important results for the development of the technological prototypes, for the Bremen SUMP and for an emission free neighbourhood were obtained. The achieved reduction in local emissions is shown in Table 6.

Table 5: Achieved reduction of local emissions

Location of shared EV	Total distance driven by EV	Observation period	Saving of CO_2 emission[1]
LP#1	811 km	06 – 12/20	136,3 kg
LP#1	5.146 km	01 – 12/21	864,5 kg
LP#2	1.276 km	06 – 12/20	214,4 kg

[1] (Consumption/100km) x (emission factor) = (CO_2 emission) [g/km]
For the shared EV: 17,2 x 0 kg/kWh = 0 [g/km]
For the potentially used private ICE car :
5,3 Liter/100km x 3,17 kg CO_2/Liter = 168 [g/km]

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

LP#2	5.032 km	01 – 12/21	845,4 kg
EURO#1	545 km	06 – 12/20	915,6 kg
EURO#1	6.497 km	01 – 12/21	1.091,5 kg
EURO#2	615 km	06 – 12/20	103,3 kg
EURO#2	7.610 km	01 – 12/21	1.278,5 kg
		TOTAL	**5.450 kg**

- Positive impact on technology prototypes

One of the main tasks of project phase II was to translate user feedback into user experiences adoptions. The Car-Sharing Frontend (CS-Frontend) had been consistently updated to guarantee an easy booking journey for the user. In addition to the appearance of the app, the service has also been significantly improved. Many processes that were previously handled by the fleet manager in direct customer contact had to be revised. Customers can now make essential changes to their account directly in the app. This also includes the regular validation process of the driver's license. Day-to-day business has also shown that the wide variety of end devices in particular has repeatedly led to unforeseen functional failures, which have not been accrued during testing. Many processes have been fundamentally revised to ensure stability. The valuable feedback from initial users is of great value for the further development of the products and the planned market launch of the key exploitable result (KER).

Use Case 3: EV CarSharing combined with public transport (system extension) (BRE.D2)

A second extension had the goal to investigate how intermodal eCar-Sharing can be promoted. The combination of car sharing and public transport depends to a large extent on the type of car sharing concept. The first possible concept is the so-called free-floating Car-Sharing concept. Cars are available in a defined area of the town. Users can book a car on the street, use it and drop it in defined dropping arears. A big challenge comes into play , if EVs are used in this mode of sharing. Shared EVs would compete with private EV drivers for the public CPs, unbooked EVs could block charging points (potential blocking fee) and it would be more expensive to buy electricity at public CPs. On the other hand, this concept would require less start investment, because it is not necessary to build own charging infrastructure, presuming public CPs are available. The second concept is the station-based car sharing which allows one-way trips between the different stations. This concept tries to combine the pros of the free-floating model with the pros of the station-based car sharing concept. Here it is possible to use EVs but that requires a high investment into the charging infrastructure. An eCarSharing station operating in such a mode needs to provide extra space for potential one-way trips, i.e., additional charging facilities have to be built and have to be kept available.

The third and demonstrated concept is the station-based mode of car-sharing. The concept is best suited to implement eCar-Sharing, because a charging station can be installed next to a reserved parking spot. The user has to return the car to the station and start the charging process, before he is able to end the booking of the car. In this way a fully charged car can be much easier offered to the next costumer. Also, the eCar-Sharing provider is in control of the charging station. This makes a more convenient costumer support possible and decreases the costs for electricity.

In the course of the MaaS expansion of our service, it became clear that the best use case for eCar-Sharing is not necessarily the best use case for the use of car sharing vehicles in a MaaS service. The reason for this are the following challenges:

- One way trips required

The actual benefit of intermodally optimized routes in a MaaS application only exists if one-way trips with the carsharing vehicle are possible. In the case of one-way trips, the user benefits from the parking of the vehicle and thus a lower total bill. However, if only round trips with the carsharing vehicle are possible, there is little incentive for the user to leave the vehicle and switch to public transport or micro-mobility services. The booked time in the carsharing vehicle must also be paid for during the parking period.

- Low usage of vehicles

The change of the sharing mode seemed to be a potential solution to the one-way trip problem, but was undermined especially by the low usage of the service. In order to enable one-way trips in a station-based eCar-Sharing service, various prerequisites had to be met. Firstly, there must be an additional free CP at each station to enable a trip from station A to station B. Secondly, it must be ensured that the EVs are brought back from station B to station A always. The most economically sensible way to solve this problem is to provide the end customer with incentives for returning vehicles, e.g., lower costs. However, this requires a large customer base with steady mobility requirements. The attempts to change the concept in the early project phase had led to undesirable results:

- Increasing customer dissatisfaction as vehicles were less often available at more frequented stations. The vehicle return from less frequented stations could not be guaranteed without interruption.
- Dissatisfaction on the part of housing corporative due to the lower visibility of the service and increasing number of complaints from residents (resulting in serious contractual issues).

As a result, the connection of mobility service providers to a central MaaS platform operating in the city promises better results with regard to the visibility of eCar-Sharing stations. Since the end of 2021, the "Fahrplaner" app provided by the public transport provider BSAG in Bremen now, displays eCar-Sharing options - in addition to bus, train, and cab. Unfortunately, due to the late release, no connection to this system could be realized during the project, but the developments are promising, especially with regard to the high user numbers of this application. The basic technical feasibility was demonstrated by linking the ZET.Share system to the MaaS prototype ZET.Link in this project (read more about it in *D2.14 Intermodal On-street Car Sharing Stations in New Housing Development).*

<u>Use Case 4</u>: Residential private charging at EV CarSharing station (system extension) (BRE.D2)

The second phase of the project served to evaluate two concepts for the improved implementation of car sharing in the neighbourhood. The use case "residential private charging at EV CarSharing Stations" should provide a possible technical and operational concept for sharing charging points. The system extension should explore how a fleet management platform for e-vehicles can be combined with charging station booking in a user-friendly way in order to a) enhance the reliability of recharging options and b) optimize the charging process with respect to cost and use of green energy (see DOA Annex I, p.:13).

A concept based on the role models designed in the reference architecture was created with detailed technical requirements for the various system components (see D2.14 *Intermodal On-street Car Sharing Stations in New Housing Development: chapter 4).*

The evaluation of the concept showed that the low interoperability readiness level of the technical systems currently available in the involved sectors, made it impossible to implement this demonstrator extension. The complexity and effort needed to implement full-fledged demonstrators was beyond what could be achieved within the budget of this project. Also, with respect to the lessons learned from the business model evaluation and the actual operation of the demonstrator, the use case appeared not suitable for a more costly fleet operation system. One of the major problems of sharing charging points with different user groups had been accounted at the CarSharing station "Ricarda-Huch-Straße". It was learned that illegally parked cars cannot be removed.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

The justifiable removal of illegally parked cars on private parking spaces requires a threat to public safety. Otherwise, the Car-Sharing company potentially needs to cover the costs of the removal.

Figure 8: Illegally parked cars blocking charging infrastructure (BRE.D2)

Most Car-Sharing companies tackle this problem by mechanically blocking the parking space. This would have required an additional investment, which was highly unlikely to pay off due to the low usage. Also, this solution could hardly support the goal to share the CP with public users without an additional implementation of an API provided by a manufacturer of electric parking bracket systems. Including the additional HW and SW integration required, this use case alone would be larger than the system presented in Oslo Demonstrator 2.

However, the experience gained from this feasibility analysis provides good implications for SUMP design. In order to realize a concept with shared charging infrastructure, it is important to have a suitable policy framework. For example, it is conceivable that penalties for parking violations can be enhanced drastically.

4 Measures and KPI's

4.1 Measures implemented in the pilot

This section will list the 3 measures taken at the Bremen pilot and describe the results.

4.1.1 Demonstrator 1 (D1) – GreenCharge@Work

The 2 GreenCharge-measures implemented in Demo1 are related to

- booking for priority charging (GC.M4) with the two sub-measures regarding a multi-station charging facility on company ground and a multi-site CS distributed across the site area
- Charging via PV energy supply (GC.M5) with the sub-measures of a charging infrastructure with PV support and the stationary buffer battery usage.

The Table below shows in more detail the measures implemented by D1 (Source D6.4)

Measure groups	Measures
Charging	• Private CPs • Flexible charging • Priority charging
Smart energy management	• Local RES • Local storage • Optimal and coordinated use of energy

Implementation of charging measures in D1:

When starting the project, four charging stations were identified in the campus area of the Bremen university intended to be used for implementation of a multi-station charging infrastructure. This concept had to be modified because of h/w issues and a rental contract that was not renewed/extended.

As a practical alternative, in the final configuration of D1 two larger carport charging stations on private ground were rented in a basic configuration as an R&D platform to facilitate the above charging measures. In the final demo phase, eleven (11) EV users had been registered. Both stations are remote controlled by a proprietary backend s/w. This enabled the deployment of a reconfigured charger comprising 2 CPs and enabled a safe and reliable data acquisition process.

Further, a web-based APP was developed that could be accessed by the user via a QR code. With this frontend interface the following input data could be acquired from the user: current SoC of their EV [%], desired amount of electric energy [kWh], and anticipated time frame, when session should end [hh:mm]. In addition, the option "priority" could be set, if a fleet EV (no commuter EV) indicates its charge demands. This user having indicated priority would get charge with max. power before other chargers are supplied, if otherwise a pre-set power limit of the local grid would be exceeded.

Implementation of SME (smart energy management) in D1:

The infrastructure comprised a PV roof-top power supply for charging stations CS#3 and CS#5 of 4,7kWp and 12kWp, respectively. The idea of deploying used EV batteries as a buffer storage follows the concept of a cycle economy, since it is expected that during this decade an increasing number of such batteries will be available for a 2nd life in stationary energy storage.

The carport systems had been used by an EV fleet consisting of more than 10 EVs before. Since this fleet had been liquidated before the carports were available for usage in the GreenCharge project, PMC took another opportunity to resolve some of the batteries from the decommissioned EVs and to integrate them into the

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

charging station CS#3 as a stationary buffer battery (2nd-life battery), whereas CS#5 was already equipped with a so-called Redox-Flow battery.

4.1.2 Demonstrator 2 (D2) – eCarSharing in a residential neighbourhood

eCarSharing in a residential neighbourhodd (defined as GC.M6 in D5.1) comprises 2 sub-measures, i.e., combine eCarSharing with public transport and with public EV charging.

The Table below shows the various aspects to be implemented in the Bremen Demo 2 (Source D6.4)

Measure groups	Measures
EV fleet	• Shared EVs • Shared EVs in new housing cooperative
Charging	• Private CPs
Business aspects	• Payment for sharing EVs • Rewarding eco driving

The following Table 6 summarizes the results of measures for BRE.D2:

Table 6: Measures in BRE.D2

Measure Group	Measure	Result
EV fleet	The number of shared EVs provided by ZET	4 Renault ZOE ZE50
Charging	The number of charge points provided	2 CPs Alfen Double Pro Line 2 CPs Alfen EV Link
Business aspects	Reduction of operating costs via digitalisation of the EV sharing	In 2021 the new build s/w and operation processes led to a reduction of operating cost by 14% compared to operation in 2018.
	The rewarding of eco-driving encourages a driving behaviour, which causes less ware on the EVs and thus a reduction of maintenance and investment costs	From a fleet management perspective, it is unlikely that eco-driving leads to a reduction of maintenance costs, since maintenance cost for EVs are pretty low and leasing contracts foster a continuous exchange of EVs. There might be a larger impact, if sharing companies own the shared cars and have to maintain them more than 5 years.
	Payment for sharing EVs	2 new revenue channels are implemented 1) Compensation payment for the suspended creation of parking space. 2) Marketing Cooperation. This led to a higher fixed revenue. The revenue out for the sharing on EVs itself remained unchanged due to low utilization

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

4.2 KPI's relevant for the Bremen demos

The following Table 7 lists the indicators that are focused in the Bremen pilot (contents aligned with D5.1).

Table 7: Indicators focused in Bremen pilot

Demo	Indicator	Category	Name	Relevant for GC measure
D1	GC 5.1	Transport - eMobility	Number of EVs	GC.M4+M5
	GC 5.2	"	Parking with charging	GC.M4+M5
	GC 5.6	Economy - Costs	Average operating costs	GC.M4
	GC 5.7	"	Capital investment	GC.M4+M5
	GC 5.11	Energy - Energy consumption	Saving	GC.M5
	GC 5.12	Energy - Fuel consumption	Vehicle fuel efficiency	GC.M4
D2	GC 5.1	Transport - eMobility	Number of EVs	GC.M6
	GC 5.6	Economy - Costs	Average operating costs	GC.M6
	GC 5.7	"	Capital investment	GC.M6
	GC 5.15	"	CarSharing development and impacts	GC.M6
	GC 6.1	Society people - Acceptance	Awareness level	GC.M6
	GC 6.2	"	Acceptance level	GC.M6
	GC 6.4	"	Operational barriers	GC.M6

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

5 Data collection

5.1 Implementation in manual and automatic mode

For the Bremen pilot static data have been collected, whereas the process of collection and uploading log-data files were tested and optimised continuously until the end of the testing phase. Real data were collected until 31 December 2021. SINTEF was responsible for the data collection and the control of data received from the Bremen pilot. Table 5 summarizes the file type of the data files and the collection method for both demos (Source: D2.13)

Table 8: Logging of working process for data collection

File type	Data file	D1	D2	Comment
Device model	PV panel models	X	-	Collected manually from technical description and data sheets for the installed system
	Inverter models	X	-	Collected manually from technical description and data sheets for installed system
	EV models	X	X	Collected in EV database having been created by PMC for all pilots within GreenCharge
	Battery models	X	-	Collected manually from technical description and data sheets for the installed system
Individual (devices)	Individual EVs	X	X	Individual Vehicle ID
	Individual Software System	X	X	Release version of Car-Sharing App
	Individual Charge Points	X	X	Charge point data
	Individual price lists	-	X	Individual price lists on energy use and CarSharing pricing
Log-files	EV charging session	X	(X)	BRE.D1: Collected as test files since 11/2020 BRE.D2: Metadata as described in D5.6 section 5.3.3.1 (no time series)
	PV session	X	-	BRE.D1: Collected automatically
	Metadata on reservation/booking events	X	(X)	BRE.D2: Metadata as described in D5.6 section 5.3.2

During the initial phase in the data collection process a major cross-pilot issue had been revealed regarding the joint vehicle database. The following example shows in which format the EV data are summarized by using the YAML files that can be exported easily in CSV-format.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

5.2 Results of data collection

This section will give a brief overview of the results and objectives achieved through the data collection. A detailed description is given in deliverable D2.13.

Data are collected in accordance with the "Research Data" document provided in D5.6 as part of WP5. The static data include information about the employed devices, i.e., the PV-devices, the buffer batteries, and the EVs. For these files technical data have been collected and the files created manually. The log-file data include both static metadata and logged values.

The log-files that were collected automatically (e.g., the charging sessions), are saved locally on an LDAP-server (PMC-Intranet) for a month time. The upload to the SINTEF file server occurred manually once per month as input to the evaluation process.

A detailed description of the evaluation results are given in deliverable D5.5.

For D1 the evaluation of the research data were partially impeded by the missing baseline data – only estimate values were available from the company. Data of more than 200 charging sessions had been acquired during 6 months period (07-12/2022), i.e., during office hours there were roughly 2 charging events for 5 CPs. The number of charge sessions did not change a lot from one month to the other. Obviously, the commuting employees used the chargers in a well-calculable way. Further, with the low occupancy ratio there was hardly any situation, where there was a need for the SEM to share/distribute capacity among users. It can be concluded that an EV/CP ratio of 2.2 is far below the maximum capacity the charging infrastructure (PV + site-grid) can handle. This situation will definitely change beyond the end of project, when the number of commuter EVs will further grow.

5.3 Challenges

This section will describe any challenges that have occurred during the data collection process and especially those that had prevented the project from collecting data as expected at the start of the project.

Data formatting (issue for all demos)

The Open Research Data Format defined in D5.6 has been specially designed for the data exchange between the pilot systems and the simulator. However, creating the static data-sets (Makes/Models/Devices/Entities) manually in this Open Research Data Format caused a lot of trouble and formatting errors.

To avoid the above issue and provide a human-friendly interface, a new YAML-based data-format has been introduced. It provides a unified device and entity modelling workflow without getting in touch with CSV-data. A converter software component merges all given files and exports them to the Open Research Data Format. Any kind of required format changes just requires minor adjustments to the converter without editing the models itself. As an intended mechanism, the converter uses UUIDv4 references to link the devices and entities. No relationships with personal data, such as the vehicle type, is exposed to the GreenCharge data repository (SFTP server), As another advantage of this procedure, implementation of an additional data anonymization process is avoided, which would be required otherwise. This component has been made available to all partners via the internal GreenCharge GitHub repository.

Low number of users

Due to COVID situation, in most of the year 2020 there were hardly any users available to test the demo's first iteration step: After a 2month lock-down the use of home-office work was obligatory. Therefore hardly any charging event could be tested during this period. Fortunately during the last 2 years in the project, home-office was recommended but not obligatory. Further in the course of the project, an increasing number of the commuting employees has bought a private EV. Thus many more employees were finally able to participate as registered users in the 2nd iteration of demo 1 starting 07/2021 (in total 11 users).

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

Data of decommissioned EV batteries (2nd-life)

A general issue in the context with using 2nd-life EV batteries for a stationary buffer energy source turned out to be the limited availability of source code for addressing the battery management system (BMS). In the past 10 years many of the start-up and SMEs having produced EVs went bankrupt and left the market. As a consequence many technical details of the traction battery system were no longer available. On the other hand, they were needed to address the BMS control software of the demounted EV batteries. This was also the case for the employed ZEBRA-Batteries ($Na/NiCl_2$-chemistry) demounted from Think-City EVs. Therefore, these data had to be simulated in the evaluation process. Of course, in principle repurposing is feasible with a new set of power electronics, software (BMS), and housing structure. This was no option and outside the project resources.

Data of CarSharing charging stations

In demo 2 charging sessions at 4 charge points had been monitored. In the first half of the project (1st iteration) data had been collected only via the in-vehicle system, which delivered the state of charge to the fleet management system continuously. However, the acquired data was difficult to use for the project's data strategy, since the other demonstrators collect log data from charging points only.

However, In the second half of the project (2nd iteration), it was possible to use the internal memory of the charging stations themselves to collect relevant research data via a diagnostic tool, which had been provided by the manufacturer before. The data collected in this way could then be merged with data from the fleet management system using the specially developed data program and made available for the evaluation process.

Data of users

Users were expected to supply some data manually via the frontend application. In Demo 1 the current SoC is acquired as a user input. Since the user typically turns off the EV before starting the charging procedure via web-based App, usually the exact SoC cannot be seen from the dashboard-display. Therefore, in general this input value is just estimated by the user with an uncertainty of about 10%. The best way to get around this issue would be the usage of technical means, e.g., by a direct communication between EV and CP occurring after being connected with charger cable. However respective communication standards are not yet provided by the OEMs.

In Demo 2 the above issue is not relevant, since the SoC data from CarSharing EVs is acquired from the in-vehicle system in the shared EVs, i.e., the OTA-key box.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

6 Guidelines for further work

6.1 Recommended procedures

This chapter summarizes the lessons learned from the Bremen pilot, and can be used as guidelines for further work related supporting wide-scale adaption of shared EVs.

1) Model of Sharing

Station-based car sharing is a good starting point for the new implementation of a car sharing service in a neighbourhood, especially in close cooperation with a housing corporative. It should be noted, however, that it may be necessary to open up the sharing model in order to attract a larger group of users. Opening up station-based car sharing to a one-way or free-floating system poses its own challenges, but is essential for growth. Overall, a higher number of stations (in the one-way system) will be required, but in return fewer vehicles will be needed. The low number of vehicles and the integration into multimodal route optimization promise an optimized return on investment. Growth should be considered the most important means of attracting the attention of large customer groups. In this context, the use of hybrid fleets can also create an advantage (especially in peripheral areas).

2) Set up of cooperation agreements for carsharing

When concluding cooperation agreements for the purpose of the mobility concept, care should be taken to ensure that a realistic demand assessment is carried out in advance by both parties to the agreement. The estimation of demand in this business case is complicated by the fact that the residential composition of the newly developed housing blocks is unknown in advance. Also, no surveys can take place since the future tenants are also not fixed. Contracts for the provision of more than two parking spaces per side should be treated with caution, especially if it is stipulated in the contract that the station may not be used in a one-way sharing concept.

3) Communication to stakeholders

One of the biggest challenges of software development in a living lab is the communication with different stakeholders. The benefits of participating in the project must be communicated to the various stakeholders in a way that is appropriate for the target group. Different focal points can arise depending on the target group:

- Communication to residents

The residents in the BRE.D2 demonstrator had to be convinced of the concept of car sharing and of the use of electric vehicles. Especially when residents have not yet had contact with EVs, a comprehensive and empathetic customer service is required. This, and the ever possible failure of systems, results in the need for detailed training of the support staff. Due to the small size of the pilot and the low usage, 24/7 support could not be offered. Customer support was mainly provided via e-mail, as telephone support could not always be guaranteed.

- Communication to housing corporative

Especially the housing corporative be kept out of customer support, this can only be done through clear communication of contact options to both the housing corporative and the residents.

It is also necessary to define clear creative scope for the service design in the formulation of the cooperation agreements for the implementation of the mobility concept.

4) Integration of 3rd party extensions

The integration of third-party providers must be well weighed financially. The low margins in the car sharing sector hardly allow additional service fees. Small providers in particular also receive poor conditions and costumer support, as the connection promises little profit for the providers. So before thinking about expensive connections to third party providers, a basic size of the service should to be reached.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

6.2 Reasons for delays and recommendations to avoid them

There are 2 major reasons for delays experienced in the course of the project:

1. The pandemic situation starting 03/2020 lead to the absence of users of charging stations and eCarSharing service in demo 1 and demo2, respectively. This situation was extremely difficult to handle, since without users no data could be generated. A workaround was to extend the testing phase by nominating project personal as test user in order to develop h/w and s/w solutions. No recommendation can be given to avoid such situation.
2. The locations of the RES charging station for commuters and the eCarSharing stations in demo 1 and demo 2, respectively, were not defined in the version, which was finally deployed. Switching from one location to another mirrors in higher effort. On the other hand, such a "screening-phase" must be allowed and is also typical in RD projects, since in the end it has a positive effect on the final choice out of a bunch of choices and opportunities envisaged during the initial project phase. However, keeping this period as short as possible is crucial for an efficient project planning.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

7 Recommendations

7.1 Replicate and further develop the implemented GreenCharge solutions

In addition to the technological prototypes presented here, two further prototypes were developed in Oslo with a focus on the energy-efficient charging of EVs and the booking of charging points via eRoaming. In view of the experiences of the GreenCharge project, it is advisable to combine the various technological prototypes if a wider range of use cases is targeted.

In the Oslo pilot, it was experienced that the data provided by vehicle users often do not meet the high requirements of energy management systems. A connection with the fleet management system developed in the demonstrator BRE.D2, almost all relevant data are generated automatically.

The developed app asks the user in Oslo to provide the following data:

- Vehicle information (make, model, battery size)
- Current battery level of the vehicle (SoC)
- Desired departure time
- Flexible or Priority Charging

The data entered is used to calculate the user's energy demand up to the specified departure time and, based on this, to set a charging plan that does not exceed the limits of the local energy grid.

In particular, the information on the vehicle and the SoC has been subject to errors. This information is managed centrally in the fleet management system developed for the Bremen pilot. The fleet manager creates vehicles based on their technical data in a web interface and connects them to the corresponding in-vehicle system. The in-vehicle system automatically transmits the SoC to the fleet management system. Furthermore, the scheduled departure time can be automatically transmitted to the energy management system on the basis of the vehicle booking. Such an integration removes the human factor from energy management, resulting in increased reliability and stability.

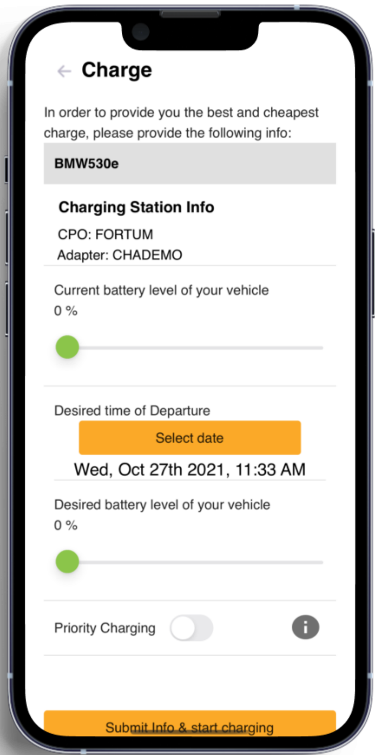


Figure 9: Screenshot "ZET.Charge" -App - Oslo Pilot

For the setup of such a system, however, an appropriate use case is required. A distinction should be made according to the usage profile of the vehicles. It is difficult to equip privately used vehicles with the necessary systems, as there may be legal hurdles such as data protection guidelines. Stations with individual charging points rarely reach the maximum of the local grid infrastructure, such as in the pilot sides in BRE.D2. The expected savings for such small pilot sides are so low that such a system cannot be operated economically.

A very interesting use case, on the other hand, is the commercial vehicle fleet with local company-owned charging infrastructure. As soon as several vehicles of a company are in use, a more precise charging planning helps to lower the investment costs, because separate charging points does not have to be installed for each vehicle. The eRoaming function demonstrated in OSL.D2 can also be used to enable company employees to charge at public charging stations.

The so-called *EV Fleet and Charge Management Prototype* as a key exploitable result was presented as a part of the horizon result booster service. An exploitation plan was drawn up with the aim of launching this prototype on the market as quickly as possible. Figure 10 illustrates the combined system consisting of the prototypes realized in the GreenCharge Project. For a detailed description of the components please refer to the following reports:

- *D2.6 Full-Scale Pilot Implementation in Building Block*
- *D2.12 Full-Scale Pilot Implementation for Car Sharing*
- *D4.4 Revised Version of Integrated Prototype*

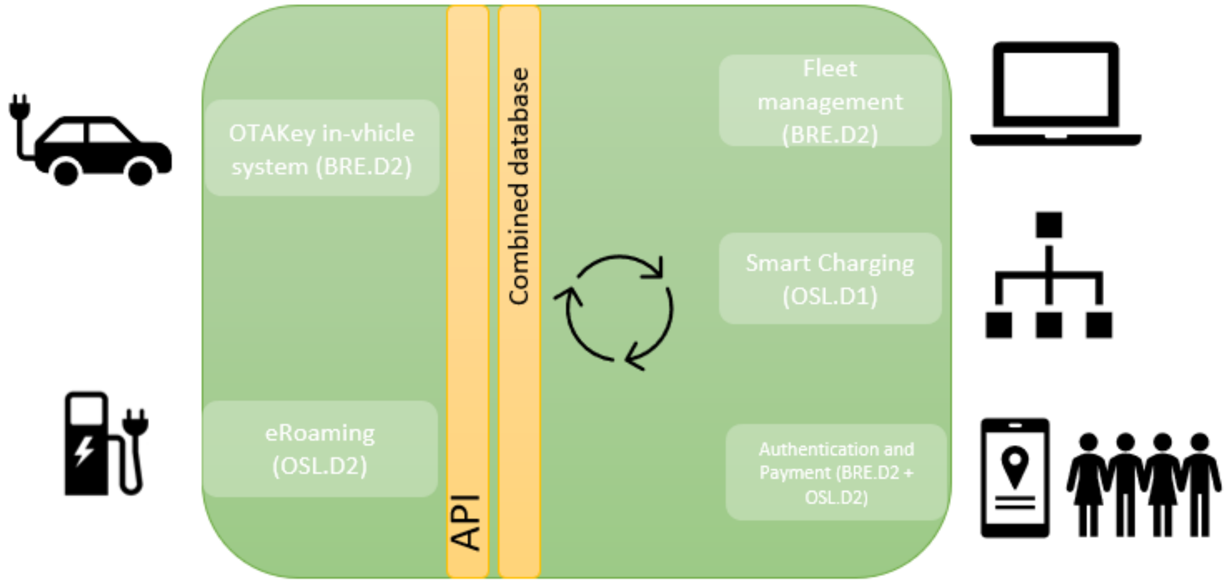


Figure 10: Combined prototype system

7.2 Inclusion of results in SUMP planning

CarSharing in urban environment is a crucial supplement to public transport options (tram, bus) and for residents it is definitely an alternative to owning a private car. This behaviour mirrors with reducing the parking pressure in the city center as concluded from earlier surveys and as described in D7.2. Since the amount of EVs will increase dramatically in the coming years, sharing e-cars is an even larger challenge, since additional charging options need to be offered in parallel to the shared EVs. Therefore having this option integrated in new housing development is a direct incentive for residents to make use of this mobility option instead of using a private car.

Further, for **employees working in urban areas** and commuting from the surrounding area there are not many alternatives to owning a private car, since public transport outside the cities operates much less frequent compared to city area. Those drivers would need public charging or preferentially a charging option near/at their workplace. In particular, production units covering a large area offer the possibility to satisfy such charging request by covering the roof with photovoltaic solar panels for electric power supply.

Thus, the results of both demonstrators have a high relevance to further develop Bremen's SUMP.

The following facts and recommendations can be drawn from the demonstrator results for implementation in SUMP processes:

- Offering eCarSharing options in new housing developments will be prospective for the residents for several reasons: Buying an own EV or a second car can in some cases be made obsolete. In particular, the combination with an obligatory solar energy supply from on-roof devices can be very prospective from a stakeholder point of view: Charging shared EVs directly (i.e., in-house) from renewable energy sources can be made profitable for the users and the owners of the property due to various economic incentives that are already implemented politically (e.g., via trading in greenhouse gas certificates).

- It has been demonstrated how a multi-mobility application may combine the eCarSharing with public transport. This MaaS option can be used in SUMP processes by making it easier for users to switch conveniently between different types of mobility options w/o using a private car. This is exactly what Bremen is promoting in its present SUMP. But an even broader implementation would need access to even more information regarding other mobility options that can then be integrated in the developed application.
- Commuters driving their own EV are difficult to consider as an important element in SUMP processes, since the number of cars would not decrease in the cities just by introducing the option to charge from RES during office hours. However, commuters travelling from surrounding areas into the city area contribute to a reduction of Bremen's CO_2 budget, if they are charging their EV from PV energy sources at the employer's site and can thus be considered as significant elements in the SUMP.
- Another alternative for commuting EV drivers to get to working place and at the same time satisfy their demand for recharging would be to use a park-and-ride option, if available. Implementation of such an option in SUMP needs to consider parking lots at the city's outer region - preferably near highway – where charging is offered from RES devices, e.g., atop of constructions similar to carports. Availability of a frequent public transport service would make this option attractive for EV drivers and further reduce Bremen's CO_2 budget.

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

8 Conclusions and Future Work

The Bremen pilot has demonstrated the positive effect of the availability of MaaS solutions and recharging options with RES with respect to the user acceptance. The low number of users due to the pandemic situation must not be interpreted as low perception. On the other hand, from the low frequency of usage and the results of user surveys it must be conceded that the user perception is closely coupled to the degree of convenience of getting access to the derived solutions. As a second aspect, for both demonstrators the availability of charging energy from RES and the reduction of total number of cars is crucial for the reduction of mobility-induced CO2 emission.

From the above conclusions and to perpetuate the growing acceptance of emobility, the following measures still need to be implemented as a follow-up activity from the Bremen demonstrators:

- eCarSharing should be implemented in new housing development as a self-evident and mandatory option offered to the residents. It would reduce the parking-pressure in urban areas, foster the reduction of private cars in city flats, and still keeping convenience for the residents with respect to their mobility needs high. Therefore the ZET.share application will be further developed for enhanced user acceptance. ZET will increase its visibility as EMP by launching a broad marketing activity to distribute/licence the developed frontend/backend solution.
- The legal regulation of the energy market in general, but in particular of the electricity market, is very complex and requires coordination of numerous stakeholders, if a specific charging infrastructure needs to be invested and operated. Ready-made systems comprising HW and SW solutions are advantageous in terms of costs and after-sale business. The backend solution integrating the demand- and supply-side for "green" charging will continue to play a key role in charging infrastructure during and after the foreseen ramp-up phase of EV market.
- Used EV batteries will come into market with large numbers during this decade, when mass-produced EVs will be decommissioned. By then stationary energy storages adapted to company parking lots or to public mobility hubs will be available. It is still unclear who will dominate this market – start-ups or the OEM's themselves. In any case, in combination with on-roof PV power supply, this option will allow the commuting employees to recharge their private EVs together with the company's fleet-EVs – cost-efficiently, conveniently, and "green"

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

Members of the GreenCharge consortium

SINTEF	SINTEF AS (SINTEF) NO-7465 Trondheim Norway www.sintef.com	**Project Coordinator:** Jacqueline Floch, Jacqueline.Floch@sintef.no **Technical Manager:** Shanshan Jiang Shanshan.Jiang@sintef.no
eSmart systems	eSmart Systems AS (ESMART) NO-1783 Halden Norway www.esmartsystems.com	**Contact:** Susann Kjellin Eriksen susann.kjellin.eriksen@esmartsystems.com
HUBJECT	Hubject GmbH (HUBJ) DE-10829 Berlin Germany www.hubject.com	**Contact:** Jürgen Werneke juergen.werneke@hubject.com
eurecat Centre Tecnològic de Catalunya	Fundacio Eurecat (EUT) ES-08290 Barcelona Spain www.eurecat.org	**Contact:** Regina Enrich regina.enrich@eurecat.org
ATLANTIS TRACKING YOUR WORLD	Atlantis IT S.L.U. (ATLAN) ES-08013 Barcelona Spain http://www.atlantisit.eu/	**Contact:** Ricard Soler rsoler@atlantis-technology.com
enchufing	Millor Energy Solutions SL (ENCH) ES-08223 Terrassa Spain www.millorbattery.com	**Contact:** Baltasar López blopez@enchufing.com
motit www.motitworld.com	Motit World SL (MOTIT) ES-28037 Madrid Spain www.motitworld.com	**Contact:** Valentin Porta valentin.porta@goinggreen.es
Freie Hansestadt Bremen	Freie Hansestadt Bremen (BREMEN) DE-28195 Bremen Germany	**Contact:** Michael Glotz-Richter michael.glotz-richter@umwelt.bremen.de
ZET zero emission transportation	ZET GmbH (MOVA) DE-28209 Bremen Germany www.zet.technology	**Contact:** Dennis Look dennis@zet.technology

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

	Personal Mobility Center Nordwest eG (PMC) DE-28359 Bremen Germany www.pmc-nordwest.de	**Contact:** Bernd Günther b.guenther@pmc-nordwest.de
	Oslo kommune (OSLO) NO-0037 Oslo Norway www.oslo.kommune.no	**Contact:** Patrycjusz Bubilek patrycjusz.bubilek@bym.oslo.kommune.no
	Fortum OYJ (FORTUM) FI-02150 Espoo Finland www.fortum.com	**Contact:** Jan Ihle jan.haugen@fortum.com
	PNO Consultants BV (PNO) NL.2289 DC Rijswijk Netherlands www.pnoconsultants.com	**Contact:** Francesca Boscolo Bibi Francesca.boscolo@pnoconsultants.com
	Universita Deglo Studi Della Campania Luigi Vanvitelli (SUN) IT-81100 Caserta Italy www.unicampania.it	**Contact:** Salvatore Venticinque salvatore.venticinque@unicampania.it
	University of Oslo (UiO) NO-0313 Oslo Norway www.uio.no	**Contact:** Geir Horn geir.horn@mn.uio.no
	ICLEI European Secretariat GmbH (ICLEI) DE-79098 Freiburg Germany www.iclei-europe.org	**Contact:** Stefan Kuhn stefan.kuhn@iclei.org **Innovation Manager:** Reggie Tricker reggie.tricker@iclei.org
	EGEN B.V. NL.2289 DC Rijswijk Netherlands www.egen.green	**Contact:** Simone Zwijnenberg Simone.zwijnenberg@egen.green

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.