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: D2.13

Technical Monitoring Report and Feedbacks (Bremen)

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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

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Executive Summary

Starting from a brief description of the Bremen pilot in terms of technologies that had been implemented in BRE.D1/D2 (section 2) and a list of the measures and the KPIs that had been decided and are relevant for the pilot (section 3), this deliverable focusses on the process of data collection, which was realized manually or in an automatic mode delivering log-files. Sections 4 and 5 describe, how the data were acquired, processed and transferred to the project server in an anonymized format. The requirements on this process are related in particular to

- Type/model of employed EVs: Since these data are typically provided manually the issue here is how to ensure correct and manageable formats
- Anonymisation of acquired data: Charging sessions must not be identified to belong to a specific person – although this is difficult to achieve, if just a few EVs/users are involved
- Data processing: How are the data managed and handled before they are uploaded to the central server in an anonymized format.

The demo "GreenCharge@work supplied data of PV electric energy production together with EV charging events performed by 11 registered users charging at the 2 stations denoted CS#3 and CS#5. The acquired data files are exemplified in section 6 showing typical graphs of EV charging and PV production.

The intention to charge from a stationary storage equipped with 2nd-life recycled EV batteries under the control of an EMS was not successful. No open protocol was available to configure the data interface with the charging points. Nevertheless, in section 7, an EMS is described that can handle and adjust the cooperative action of PV energy production, overnight re-charge of a stationary storage battery, and booking of CPs for charging EVs during working hours.

Finally, as a concluding summary, in section 8 the lessons learnt from the Bremen pilot are outlined. Major conclusions for future developments are related to the following aspects:

- Data formatting and anonymization can be realized best by using a YAML-based strategy. With the described process the technology prototype could deliver reliable charging data with no formatting issues.
- H/W design and programming can be closely coupled, if implemented software is freely accessible for designing the backend. The technology prototype developed for CS#3 could be easily duplicated for CS#5 and similarly can even be extended to integrate other ones within, e.g., Bremen city or the surrounding area.

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List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
CMS	Charge Management System
CP	Charge Point
CS	Charging Station (usually comprising a multitude of CPs)
CSV	Comma-Separated Values (data format for a text file that can be stored or can export/import simple data mostly to/from excel-files)
EV	Electric Vehicle
Git	Distributed Version Control System (working for Unix/Linux and MS-Windows environment)
KPI	Key Performance Indicator (used to quantify the impact of a measure)
OTA-Key	("Over-The-Air") keyless unlocking via bluetooth communication with mobile device
UUID	Universally Unique IDentifier

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List of Definitions

Table 2: List of definitions

Definition	Explanation
Log-file	File with data that are acquired automatically via software
KPI	Key Performance Indicator used to quantify the impact of a Measure (see below).
Measure	Any integrated technology, business models or general activity implemented to improve sustainable mobility. The extent to which a measure succeeds in achieving its objective is assessed using KPIs (see above).
YAML	Human-readable data serialization standard that can be used in conjunction with all programming languages and is often used to write configuration files

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1 About this Deliverable

1.1 Why would I want to read this deliverable?

This deliverable is a technical report describing the status of the Bremen pilot at an intermediate stage. It describes the details of data acquisition process in the 2 demonstrators and how the combined feed of power from the various employed sources to the chargers is optimised. Further, feedbacks from commuting employees and users of eCar-Sharing as well as other stakeholders are summarized and will contribute to the final report D2.15.

1.2 Intended readership/users

This deliverable will be of interest mainly for project partners in GreenCharge, in particular for those, who are involved in data evaluation. In particular, data acquisition, storage, transfer and evaluation of large amount of data respecting the data protection framework as described in this deliverable might be useful for involved partners, e.g., when working out lessons learnt.

1.3 Other project deliverables that may be of interest

The situation of the Bremen pilot before starting the project and the planning for implementation of the tests in the Bremen pilot has been described in more detail in the following deliverables:

- **D2.9 Description of Bremen Pilot and User Needs** – This deliverable describes the Bremen pilot in terms of existing mobility solutions, use cases, scenarios, stakeholders and location of the demonstrators.
- **D2.10 Implementation Plan for Bremen Pilot** – This deliverable describes the planning of the tests to be carried out at the pilot site with its 2 demonstrators. It includes details on scenarios to be demonstrated, time schedules, selected stakeholders and locations, hardware and software to be installed, data to be collected, etc.
- **D2.12 Full-Scale Pilot Implementation for CarSharing** – This deliverable describes the H/W and S/W components in detail that finally has been adapted and implemented for the testing phase for both demonstrators in Bremen.

The other two "sister" pilots in the project are providing the following similar deliverables:

- **D2.7 Technical Monitoring Report and Feedbacks (Oslo)**
- **D2.20 Technical Monitoring Report and Feedbacks (Barcelona)**

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 Pilot description

In the Bremen pilot there are the following two demonstrators:

(a) the GreenCharge@work (BRE.D1) demonstrator aims at peak-shaving during working hours of commuting employees driving EVs in order to prevent the need for investing in the local grid. This effect should be enabled by renewable energy (PV) and (inexpensive) 2nd-life battery storage both deployed on private company ground. Further, priority charging should be possible for a predefined group of people (e.g. visitors) and/or electric vehicles (EVs) of the company fleet. For this purpose, data from charge events together with power supply data from RES and battery storage data are used to optimise the individual user experience with respect to convenience and reliability of charging.

(b) The eCarSharing (BRE.D2) demonstrator aims at the user-friendly combination of booking-App and charging options in a mobility-hub environment. Integration of public transport timetable and the possibility for residents to get access to the CarSharing chargers (if unused) is considered and tested.

In total three use cases (UC) had been derived for the Bremen pilot and will be the test beds to demonstrate how the defined scenarios can be solved:

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

For a more detailed description of the pilot site, we refer to *D2.9 Description of Bremen Pilot and User Needs*. The planning of the tests to be carried out and the deployment/testing of HW and SW components to be used in the pilot are described in *D2.10 Implementation Plan for Bremen Pilot* and *D2.11 Pilot Component Preparation for Full-Scale Pilot*, respectively. And finally, the content of surveys and interviews for this pilot can be found in D6.3.

2.1 Implemented technologies

Table 3 presents the status of technologies that has been or still is in the status of being implemented. The overview is based on the Technological requirements from *D2.9 Description of Bremen Pilot and User Needs*. It also includes technologies that have been left out.

See also D2.12 *Full-Scale Pilot Implementation* for details on the modified and implemented components.

Table 3 - Status of technologies Bremen pilot

Technology	BRE.D1	BRE.D2	
Charge points / Charging infrastructure	CS#1: abandoned (rental contract quitted); not used in full-scale pilot CS#2: installed (using off-the-shelf components) CS#3: 2 CPs installed CS#4: 2 CPs installed (no automatic acquisition of charge data possible); not used in full-scale pilot CS#5: 3 CPs adapted to CMS (replaces CS#1)	CS#LESUM: 2 CPs (accessible to shared EVs only) CS#EURO: 2 CPs (accessible to shared EVs only)	

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Technology	BRE.D1	BRE.D2	
EV in-vehicle system	N/A	Installed in 4 EVs (OTA-Key box)	
PV panels	Installed (CS#3)	N/A	
Stationary battery	Installed (CS#3) - second life batteries defective; Backup system (CS#5) defective after a few month	N/A	
Charge Management System	Implemented (gridctrl)	N/A	
Charging Station Frontend (APP)	Implemented (PMC-APP “GreenCharge”)	Implemented (ZET-APP in use); GC-APP to be adapted planned	
eRoaming platform	Discarded; private/corporate stations not yet supported by commercial systems	unplanned; (not considered prospective)	
Charge point booking system	Implemented (PMC-APP “GreenCharge”)	N/A	
Multi-mobility service APP	N/A	In progress	
Local Energy Management	Installed (gridctrl.aggregator)	N/A	
Fleet management system	N/A	Implemented	

In the following Table 4 the status of the data sources, being used, e.g., for KPI calculation, is summarized for the two demonstrators.

Table 4 - Status data sources

Data origin	Data source	Gateway	Data aggregation	BRE.D1	BRE.D2
PV production	Smart Meters	Gridctrl.aggregator	gridctrl	CS#3 and CS#5 charging stations	N/A
In-vehicle databus system	EV	OTA Key	ZET fleet management	N/A	In-Vehicle CarSharing Systems
Chargepoint State	EVCC Chargepoint controllers	Gridctrl.aggregator	gridctrl	CS#3 and CS#5 charging stations	N/A
Battery State of Charge	Battery Management Systems	Gridctrl.aggregator	gridctrl	ZEBRA 2nd-life (used) batteries CS#3	N/A

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Data origin	Data source	Gateway	Data aggregation	BRE.D1	BRE.D2
Battery State of Charge	Smart Meters	Gridctrl.aggregator	gridctrl	CellCube Redox Flow Battery CS#5	N/A

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3 Decided measures and KPI's for Bremen pilot

See *D5.1/D6.1 Evaluation Design / Stakeholder Acceptance Evaluation Methodology and Plan* for description of measures and key performance indicators (KPI) for the GreenCharge project and for each of the pilots.

3.1 Measures for Bremen pilot

Three measures had been decided for the Bremen pilot:

- GC.M4: Booking for priority charging: Priority is given to a pre-defined list of people and registered EVs, such as guests visiting the company with an EV and company fleet EVs, respectively. Both would need a recharge with priority - before employees commuting with their private EVs may use the determined CPs.
- GC.M5: Charging via PV energy supply: The CMS is designed in such a way to use electricity both from PV-roof and from stationary batteries (to be recharged overnight) in order to realize peak-shaving and thus prevent expensive investment in the company's power grid.
- GC.M6: EV Car-Sharing in residential neighbourhood: Usually CPs are reserved for the Car-Sharing EVs. It will be tested whether residents in the same neighbourhood could use these CPs during the booked time slot, i.e., when shared EVs are absent. Further, integration of the Car-Sharing service will be tested as part of the MaaS scenario aspect.

3.2 KPIs from D5.1/D6.1 for Bremen pilot

The following Table 5 summarizes the KPIs to be calculated and the respective data to be acquired for the Bremen pilot in order to be able to assess the effect of the 3 measures defined for the demonstrators BRE.D1 and BRE.D2.

Table 5 - List of decided KPIs for Bremen pilot

Demo	KPI	Description (measure)	Category (sub-category)	Data to be collected	Data collection method
D1	GC5.1	Number of EVs (GC.M4 – booking for priority charging (GC.M5 – Charging via PV energy supply)	Transport (eMobility)	Total number of EVs that are principally allowed to charge on BRE.D1	manually
	GC5.2	Parking with charging (GC.M4, GC.M5)	Transport (eMobility)	Total number of parking spaces equipped with CP at BRE.D1	manually
	GC5.6	Avg. operating costs for charging station (GC.M4)	Economy (Costs)	Costs for running the business/service [€] per CP	Calculated manually
	GC 5.7	Capital investment costs for charging station (GC.M4, GC.M5)	Energy (Costs)	Costs for CS setup [€] per CP	Calculated manually

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Demo	KPI	Description (measure)	Category (sub-category)	Data to be collected	Data collection method
	GC 5.10	Peak-to-average ratio (GC.M4, GC.M5)	Energy (Fuel consumption)	Calculated from log-files	Calculated from log-files
	GC 5.11	Saving (GC.M5)	Energy (Energy consumption)	Calculated manually	Calculated manually
	GC 5.12	Vehicle fuel efficiency (GC.M4)	Energy (Fuel consumption)	Calculated manually	Manually
D2	GC 5.1	Number of EVs (GC.M6 – EV Car-Sharing in residential neighbourhood)	Transport (eMobility)	Total number of Car-Sharing EVs; Total number of private EVs in neighbourhood	Manually
	GC. 5.2	Number of charging points	Transport (eMobility)	Total number of Charge Points registered at pilot site	Manually
	GC 5.6	Avg. operating costs for eCar-Sharing (GC.M6)	Economy (costs)	Costs for running the business/service [€ per Shared EV]	Calculated manually
	GC 5.15	Car sharing development and impacts (GC.M6)	Economy (Costs)	Increasing number of costumers [%]; revenue increase [%]	Manually
	GC 6.1	Awareness level (GC.M6)	Society-people (Acceptance)	Surveys/Interviews	Surveys/ Interviews
	GC 6.2	Acceptance level (GC.M6)	Society-people (Acceptance)	Surveys/Interviews	Surveys/ Interviews
	GC 6.4	Operational barriers (GC.M6)	Society-people (Acceptance)	Interviews	Interviews
	GC 6.6	Shared EVs per capita (GC.M6)	Transport (eMobility)	Data from vehicle registration office and/or statistics	Registered at pilot site

3.3 Data collected by Software according to the research data document

Data are collected by SW in accordance with the "Research Data" document provided in *D5.6 Open Research Data* as part of WP5. The collected data will be used for calculating the KPIs within WP5 (*D5.4 Intermediate Result for Innovation Effects Evaluation, D5.5 Final Result for Innovation Effects Evaluation*).

Datapoints : timestamp<>value entry within the database

The respective log-files for the Bremen demonstrators are listed in the following Table 6.

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Table 6 - Data collected automatically by S/W (log-file)

Demo	What – which data?	Delivered by whom?	Time period of data collection	Number of Data points/Datasets	Number of Log-files
D1	Number of EVs	PMC	-	-	-
	Number of CPs	PMC	-	-	-
	Plug-in time [h]	PMC	1/CP per session	X sessions from Y CPs	X*Y
	EV-charging [kWh/kW]	PMC	1/session	X sessions from Y CPs	X*Y
	PV production [kWh]	PMC	1/month	X months from 1 PV device	X
	Battery charging/ discharging [kWh]	PMC	1/month	X months from 1 energy storage module	X
	Energy cost from local grid	PMC	1/month	X months from 1 location	X
D2	Number of EVs	ZET	-	-	-
	Number of CPs	ZET	-	-	-
	Booking of EVs	ZET	1 per booking event	X bookings for Y EVs	X*Y
	Booking of CPs	ZET	1 per booking event	X bookings for Y CPs	X*Y
	…	ZET	…	…	…

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4 Description of collected data

4.1 Description of the process of data collection

For the Bremen pilot static data have been collected, whereas collection and uploading log-data files were still in a phase of testing and optimisation before the testing phase ended. 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 7 summarizes the file type of the data files and the collection method for both demonstrators.

Table 7 - Logging of working process for data collection in BRE.D1 and BRE.D2

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 in GC
	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	X	Individual price lists on energy use and CarSharing pricing
Log-files	EV charging session	X	(X)	BRE.D1: Collected as test files since Nov2020 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

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4.2 Description of challenges regarding data collection

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

4.2.1 Device and Entity Modelling

To avoid the above issues 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.

Structural Concepts

- Models/Entities can be created on a "higher level" taking care of logical structures
- YAML files can be kept under strict version control (Git) to track any changes
- Origin data (YAML files) can contain non-anonymized data that are getting stripped by the exporter
- System change-logs are expressed as standard markdown change-log including additional timestamps
- CSV output format can be easily modified/changed **without** changes to the models
- Additional metadata fields can be added to the files which is required for debugging
- Each model definition has its own YAML file
- UUID-v4 is used for each model as MakeM reference
- Additional metadata fields like model/description/UUID are added.

Figure 1 shows as an example the ZEBRA Battery Model written in YAML-based data format.

12 lines (12 sloc) | 241 Bytes

```yaml
type: battery
uuid: 72528559-b5f2-491b-aaf1-9e71ce0040c5
vendor: FIAMM SONICK
model: Think City
params:
    Type: other
    Capacity: 27.0
    CEfficiency: 0.95
    DisCEfficiency: 0.95
    MaxCPower: 12
    MaxDisCPower: 30
    Cycle: 3000
```

Figure 1 - ZEBRA Battery Model written in YAML

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.

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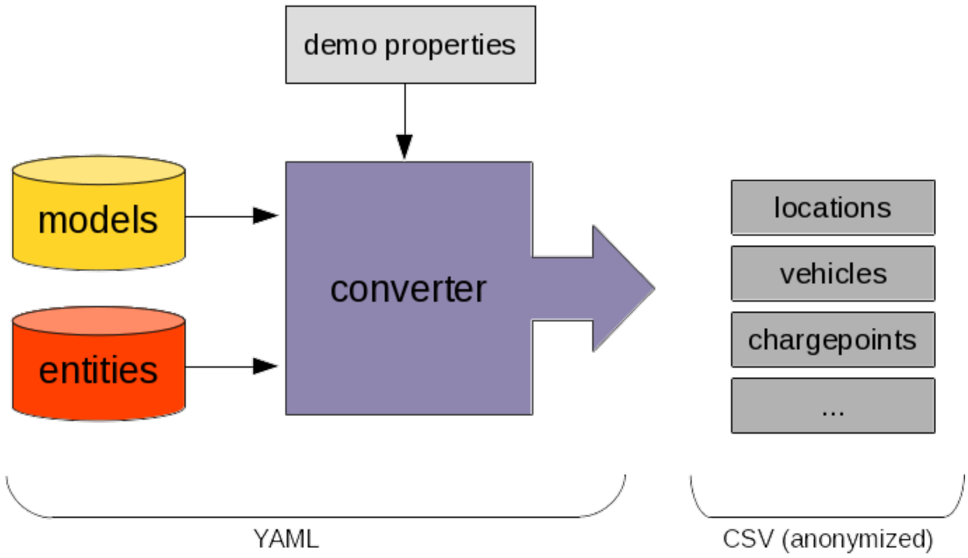


Figure 2 - Converter Software workflow merging multiple device and model files

As an intended mechanism, the converter uses UUIDv4 references to link the devices and entities. No kind of personal data, such as the vehicle type, is exposed to the GreenCharge data repository (SFTP server), As a further advantage such a procedure also avoids the implementation of an additional data anonymization process that would be required otherwise!!

This component has been made available to all partners via the internal GreenCharge GitHub repository.

4.2.2 GreenCharge joint EV database

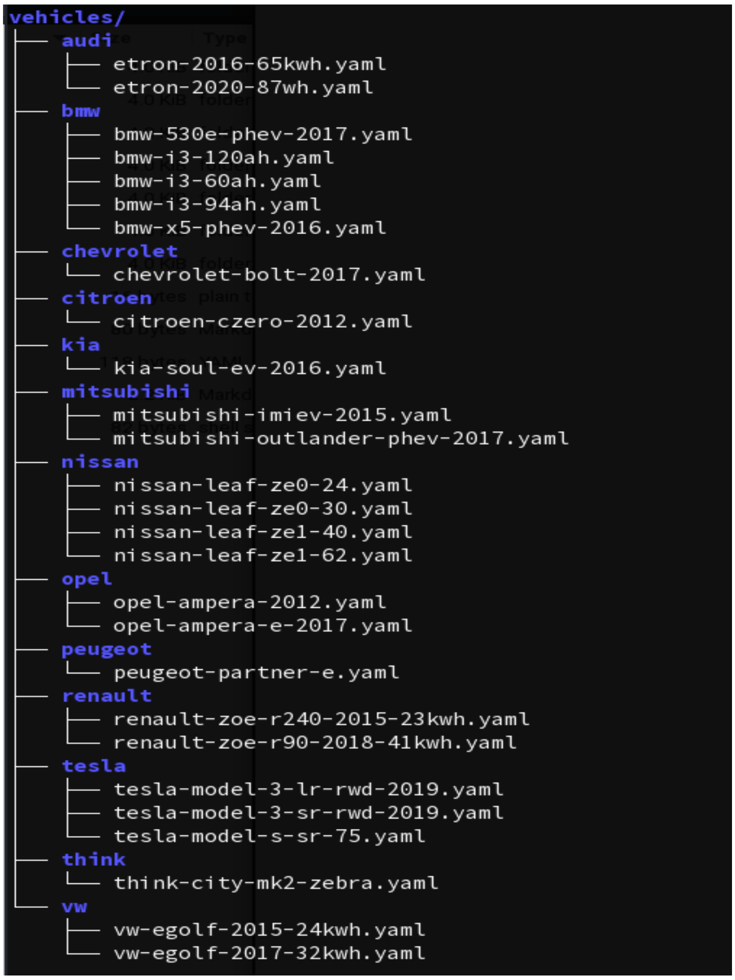
During the initial phase in the data collection process a major cross-pilot issue had been revealed, i.e. the joint vehicle database. The following example shows in which format the EV data are summarized by using the YAML files that can be exported easily in csv-format.

19 lines (18 sloc) | 460 Bytes

```yaml
type: vehicle
uuid: 2b2b92bc-a330-4c24-b33a-b5159ebe947c
author: Andi <a.dittrich@pmc-nordwest.de>
reference: https://de.wikipedia.org/wiki/BMW_i3
vendor: Bayerische Motoren Werke Aktiengesellschaft
model: i3-94-gen1
battery: li-ion
params:
    BatCapNameplate: 33.2
    BatCap: 27.2
    EffCharAC: 0.82
    EffDischarAC: null
    MaxChPwrAC: 11.0
    MaxChPwrDC: 50
    MaxDischPwrAC: null
    MaxDischPwrDC: null
    EffCharDC: 1.0
    EffDischarDC: 1.0

```

Figure 3 - BMWi3 vehicle model written in YAML including enhanced data (example)



```
vehicles/
├── audi
│   ├── etron-2016-65kwh.yaml
│   └── etron-2020-87wh.yaml
├── bmw
│   ├── bmw-530e-phev-2017.yaml
│   ├── bmw-i3-120ah.yaml
│   ├── bmw-i3-60ah.yaml
│   ├── bmw-i3-94ah.yaml
│   └── bmw-x5-phev-2016.yaml
├── chevrolet
│   └── chevrolet-bolt-2017.yaml
├── citroen
│   └── citroen-czero-2012.yaml
├── kia
│   └── kia-soul-ev-2016.yaml
├── mitsubishi
│   ├── mitsubishi-imiev-2015.yaml
│   └── mitsubishi-outlander-phev-2017.yaml
├── nissan
│   ├── nissan-leaf-ze0-24.yaml
│   ├── nissan-leaf-ze0-30.yaml
│   ├── nissan-leaf-ze1-40.yaml
│   └── nissan-leaf-ze1-62.yaml
├── opel
│   ├── opel-ampera-2012.yaml
│   └── opel-ampera-e-2017.yaml
├── peugeot
│   └── peugeot-partner-e.yaml
├── renault
│   ├── renault-zoe-r240-2015-23kwh.yaml
│   └── renault-zoe-r90-2018-41kwh.yaml
├── tesla
│   ├── tesla-model-3-lr-rwd-2019.yaml
│   ├── tesla-model-3-sr-rwd-2019.yaml
│   └── tesla-model-s-sr-75.yaml
├── think
│   └── think-city-mk2-zebra.yaml
└── vw
    ├── vw-egolf-2015-24kwh.yaml
    └── vw-egolf-2017-32kwh.yaml
```

Figure 4 - Vehicle database overview (Oslo and Bremen pilots only)

Table 8 - Exported Vehicle Database in CSV format - fully anonymized

MakeM	BatCap Nameplate	BatCap	EffCharAC	EffDischarAC	MaxChPwrAC	MaxChPwrDC	MaxDischPwrAC	MaxDischPwrDC	EffCharDC	EffDischarDC
09EB7117-5094-49E3-B752-B8F9269F3056	null	64.7	0.9	null	11	null	null	null	1	1
5004DDDE-075F-4E4B-9255-3480012B30D2	null	86.5	0.9	null	11	null	null	null	1	1
8EA88DCC-4912-4493-A910-5B37A8A2EB66	null	8.1	0.86	null	3.7	null	null	null	1	1
F8815CE9-E638-4F0B-B6C2-52239F68E145	42.2	37.9	0.9	null	11	50	null	null	1	1

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.

4.3 Data quality assurance

The acquired data were up-loaded to the project server on a monthly basis. The only data missing were those related to the energy storage systems, both h/w components could not be set into operation (CS#3) or received a serious defect (CS#5).

The quality of some manual data must be considered to contain some error (human factor). The actual SOC data of the EV is acquired as a user input. Since the user typically turns off the EV before starting the charging procedure via web-based app, the exact SOC cannot be seen from the display and therefore the input value is then estimated. The best way to get around this issue is by using technical means, e.g., by a direct communication between EV and CP occurring after cable connection. Respective communication standards are not provided by the OEMs.

4.4 Data processing

Anonymisation of research data is an important step before open data can be processed any further for evaluation and simulation. In the following Table 9 the anonymization process of research data are described for data categorised in the three file types.

By design, all entries are identified by a random universally unique identifier (UUIDv4)

Table 9 - Anonymisation of research data

Filetype	Data element	D1	D2	Comment
Device models				
EV models	EV model	X	X	A joined EV database for all 3 pilots has been established. EV model names/types are replaced with UUID in order to keep models anonymous that are seldom used
Battery models	Battery model	X	-	Models are identified by random UUID, no personal data included (infrastructure)
Inverter models	Inverter model	X	-	Models are identified by random UUID, no personal data included (infrastructure)
PV panel models	Device model	X	-	Models are identified by random UUID, no personal data included (infrastructure)
Sensor Models	Device model	X	-	Models are identified by random UUID, no personal data included (infrastructure)
Individuals				
Locations	Location ID Demo ID	X	X	Anonymized by common scheme (D5.6)
Individual EVs	EVID	X	X	Entities are identified by random UUID, no personal data included
Individual Solar Plants	SolarPlantID LOC	X	-	Entities are identified by random UUID, no personal data included (infrastructure). Locations are anonymized by common location scheme (D5.6)

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Filetype	**Data element**	**D1**	**D2**	**Comment**
Individual Charge points	CPID LOC	X	X	Entities are identified by random UUID, no personal data included (infrastructure). Locations are anonymized by common location scheme (D5.6)
Individual Software Systems	Software System id	X	X	No personal data is included.
Individual Sensors	Sensor ID LOC	X	-	Entities are identified by random UUID, no personal data included (infrastructure). Locations are anonymized by common location scheme (D5.6)
Individual Stationary Batteries	Bat ID LOC	X	-	Entities are identified by random UUID, no personal data included. Locations are anonymized by common location scheme (D5.6)
Individual Energy Meters	Meter ID Location ID	X	-	All energy meters are handled as “sensors”
Individual price list	PriceList ID LOC	X	X	Entities are identified by random UUID, no personal data included (infrastructure); Locations are anonymized by common location scheme (D5.6)
Individual tariff scheme	PriceList ID TariffID	X	X	Entities are identified by random UUID, no personal data included (infrastructure); Locations are anonymized by common location scheme (D5.6)
Log-files				
Metadata entries on reservation/booking events	CPID LOC EVID	X	-	Entity relations are linked by UUID. Locations are anonymized by common location scheme (D5.6)
Metadata entries on energy consumption and production	CPID LOC EVID	X		Entity relations are linked by UUID. Locations are anonymized by common location scheme (D5.6)
Solar plant sessions	PlantID	X	-	Entity relations are linked by UUID.
Battery sessions	BatID	X	-	Entity relations are linked by UUID.
Energy import and export	Meter ID	X	-	Entity relations are linked to UUID
Average grid mix in local grid	LOC	X	X	Locations are anonymized by common location scheme (D5.6)

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Filetype	Data element	D1	D2	Comment
Average grid mix in public grid	LOC	X	X	Locations are anonymized by common location scheme (D5.6)
Variable energy cost in local grid and public grid	LOC	X	X	Locations are anonymized by common location scheme (D5.6)

4.4.1 Vehicle anonymization

Table 10 and table 11 show a typical example of the way, how to anonymise the EV model that has been charging at one of the 2 charging stations.

Table 10 - Vehicle model (excerpt)

MakeM	BatCap Nameplate	BatCap	EffCharAC	EffDischarAC	MaxChPwrAC	MaxChPwrDC	MaxDischPwrAC	MaxDischPwrDC	EffCharDC	EffDischarDC
8EA88DCC-4912-4493-A910-5B37A8A2EB66	null	64.7	0.9	null	11	null	null	null	1	1

Table 11 - Vehicle entities referencing the vehicle type by its UUID (EVID)

EVID	MakeM	EntryTime	ExitTime	Mileage
b330e812-09f9-4fad-ae39-4287ae44fa25	8EA88DCC-4912-4493-A910-5B37A8A2EB66	20200101T000000	null	021412

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 Mechanisms for collecting feedback

Feedback from the various stakeholders was collected via different means. The type of feedback and the means to handle them is described in table 12. Particularly useful are the feedbacks from the users and drivers, because they are directly confronted with the charging system and sometimes indicate additional challenges from a user perspective.

Table 12 - Mechanism for collecting feedback from EV users and other stakeholders

Mechanism	Date / when?	Type of user / Who?	D1	D2	Type of feedback & How to handle it
Surveys (outside GC)	Before start of project	citizen	-	X	A comparative survey (team red) is available from BREM; the results in some topics are compared with the respective results from GC-surveys
Surveys (within GC)	In preparation	Neighbourhood residents; EV drivers	-	X	A JotForm is prepared to be used for a survey. Residents of the local neighbourhood will be informed via flyers with QR-codes. Additional information about GreenCharge will be presented. Results will be used to report on KPIs defined in WP5.
Interviews	In preparation	EV drivers; Fleet manager	X	-	The results of the interviews will be input for WP6 and can be read in D6.3
email	Available through the whole project	All registered users	X	X	Feedback via email-account GreenCharge@pmc-nordwest.de that had been communicated to all users of our CPs (BRE.D1); Hotline support via callback; in severe cases physical visit of the CP/user (BRE.D1/D2)
questionaire	In preparation	EV drivers	-	X	For getting feedback for the EV users of CarSharing it is planned to include the questionnaire in the ZET-APP
Workshop	Dec2018	Members of Local Reference Group	X	X	Minutes of meeting available; results assessed in D3.2
On-Site Support	Available through the whole project	Corporate EV Users	X	-	Internal Records within Customer Management

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 Monitored data

In the following graphs examples of the collected data are presented. These are

- Some EV charging profiles collected at CS#3
- Solar energy drawn from both roof-top carports during pilot operation

Electric energy drawn from battery storage during operation could not be measured, since integration into the charging system failed. Furthermore, since no in-line meters for the 2 carports were allowed to be installed, the electricity drawn from the local grid was not obtained.

6.1 EV charging

EV-charging processes were followed with a sampling rate of 0,1….0,2Hz (10….5sec per data point)). Users are owning various types of EVs, such as Tesla Model3, Renault ZOE, VW e-up, Polestar, and Opel Ampera. The respective typical charging curves obtained from CS#3 are shown in Figs. 5-8.

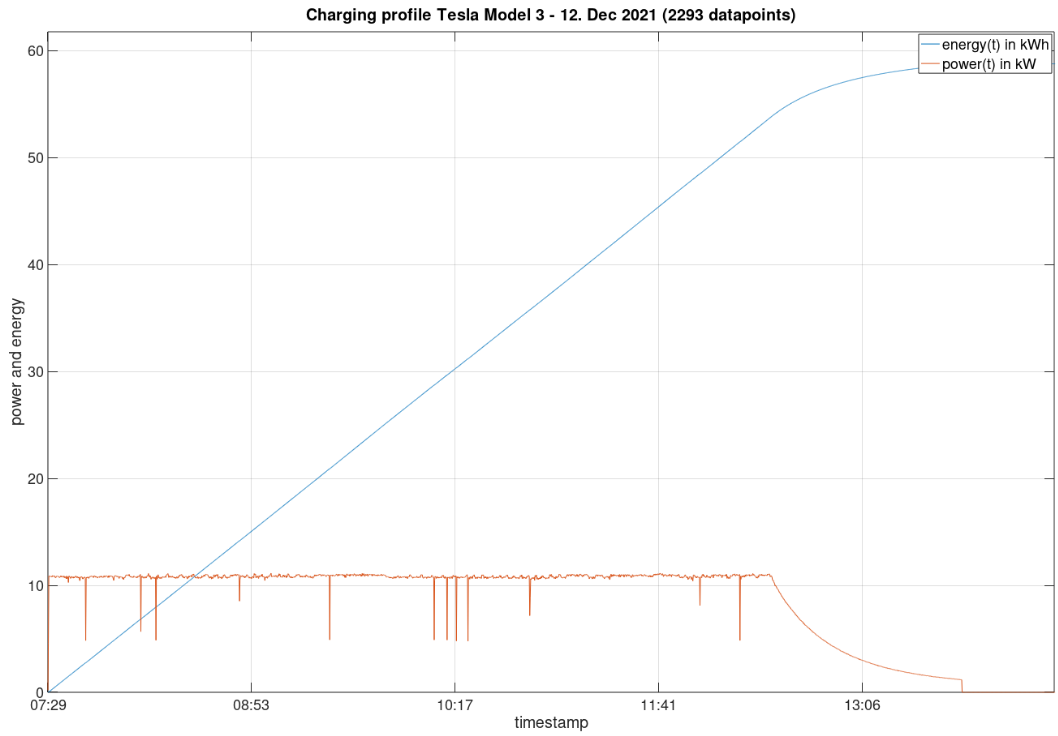

Figure 5 - Charging curve of a Tesla Model 3

Figure 5 shows a charging curve of Tesla EV (Model 3) charged with 11 kW @CS#3 and a data acquisition rate of 0,1Hz. The spikes in the power curve are artefacts not reflected in the energy profile. Characteristic feature is a smooth phasing out in the final 90 min of the charging session.

Figure 6 shows a charging curve of a Renault ZOE (new generation built 2019) charged at 10,5 kW @CS#3 with a data acquisition rate of 0,16Hz.

Figure 7 shows a charging curve of a VW e-up! (new generation built 2020) charged at 7 kW @CS#3 with a data acquisition rate of 0,16 Hz.

Figure 8 shows a charging curve of a Polestar EV (built 2021) charged at 11 kW @CS#3 with a data acquisition rate of 0,2 Hz.

Figure 9 shows a charging curve of an Opel Ampera hybrid vehicle (built 2011) charged at 3,2 kW @CS#3.

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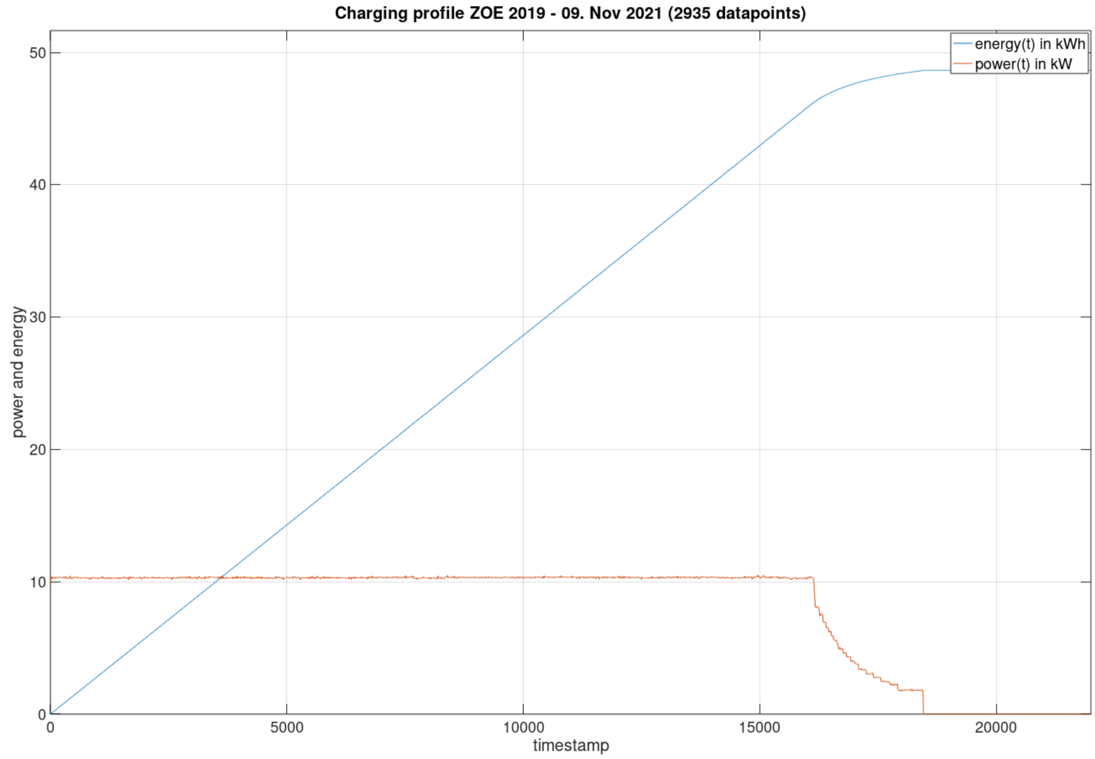

Figure 6 - Charging profile of a Renault ZOE

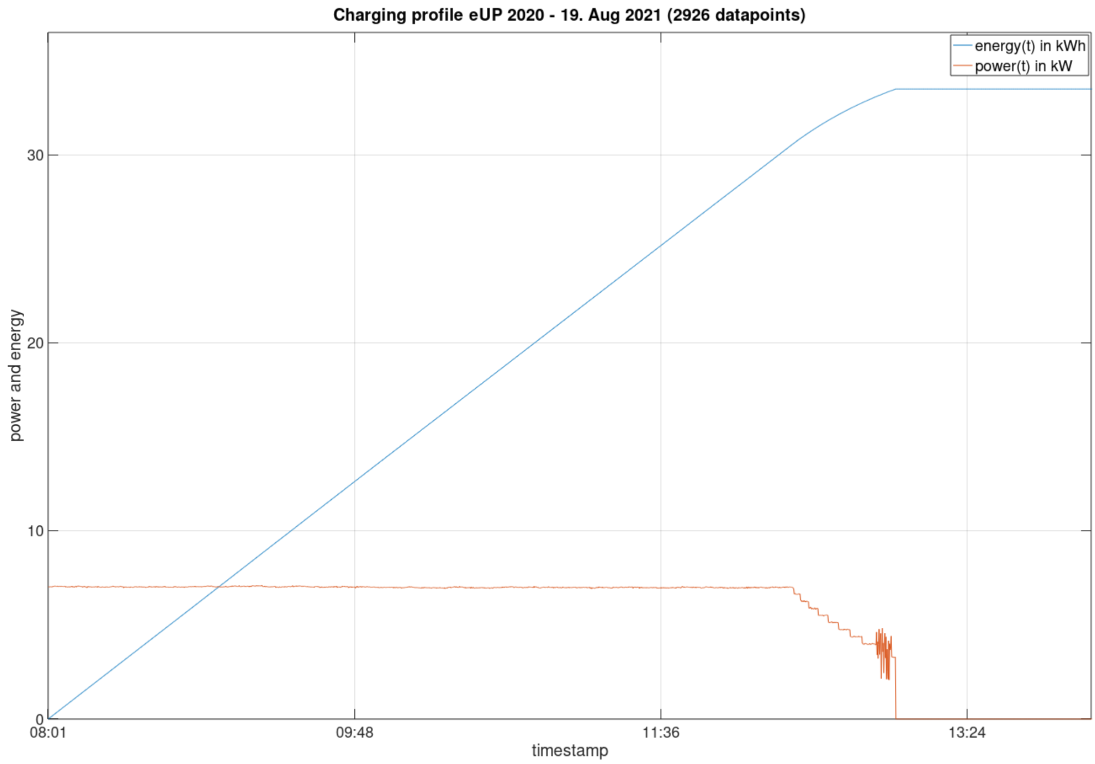

Figure 7 – Charging profile of VW e-up!

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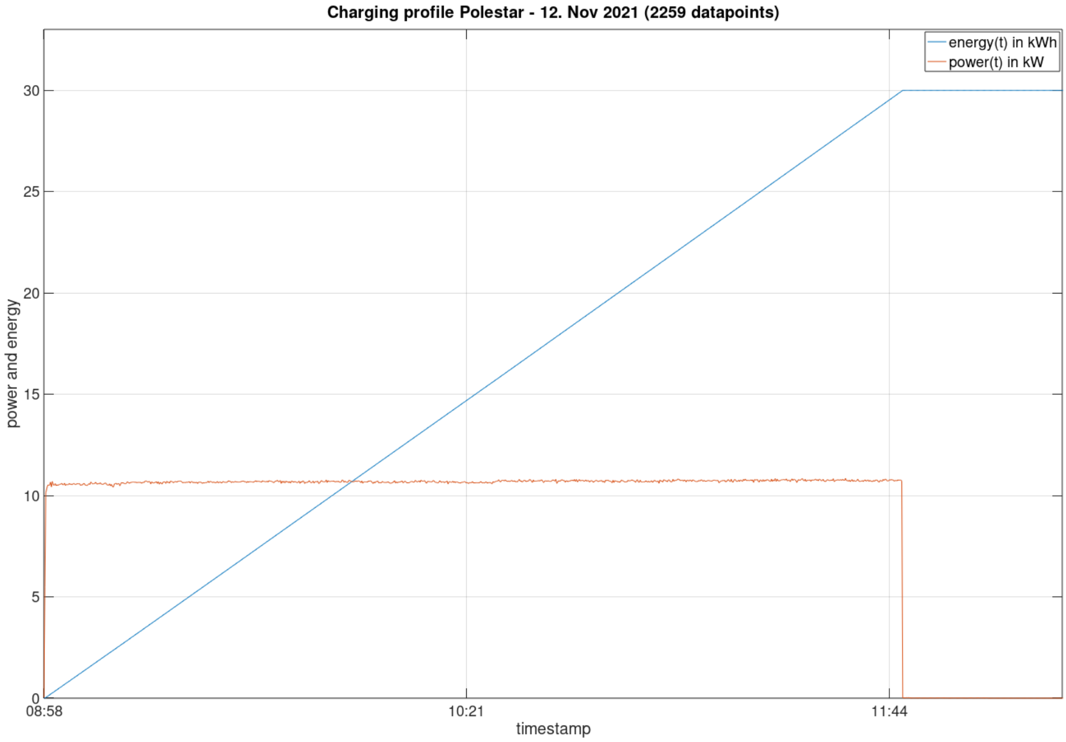


Figure 8 - Charging profile of a Polestar EV

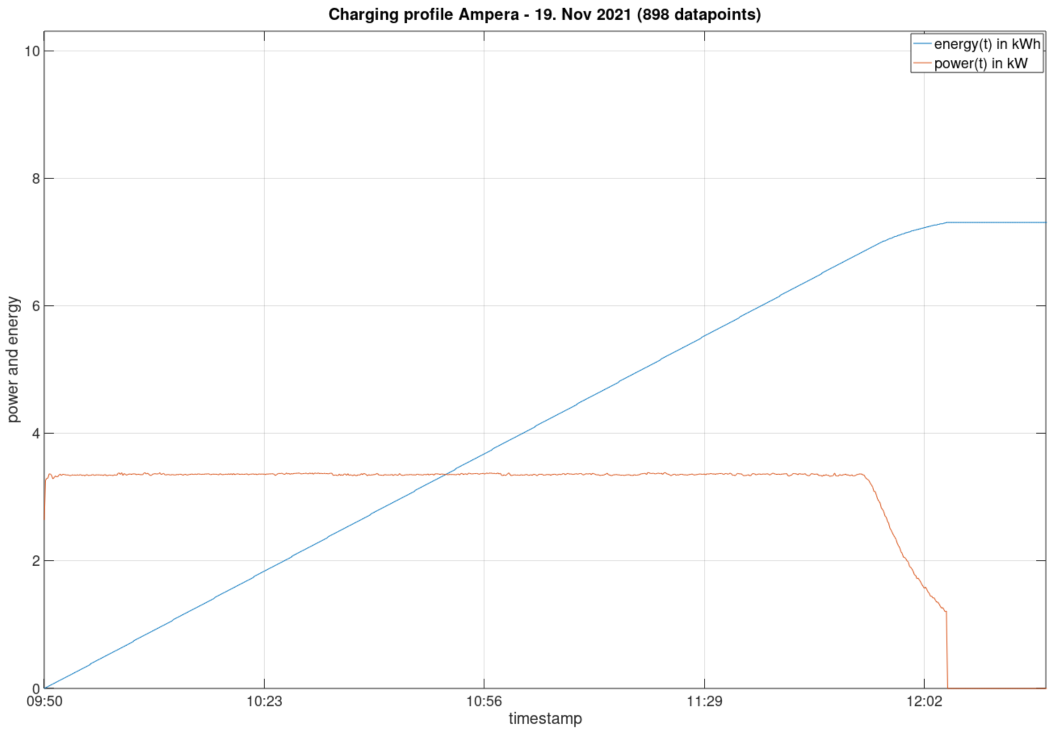


Figure 9 - Charging profile of an Opel Ampera EV (built 2011)

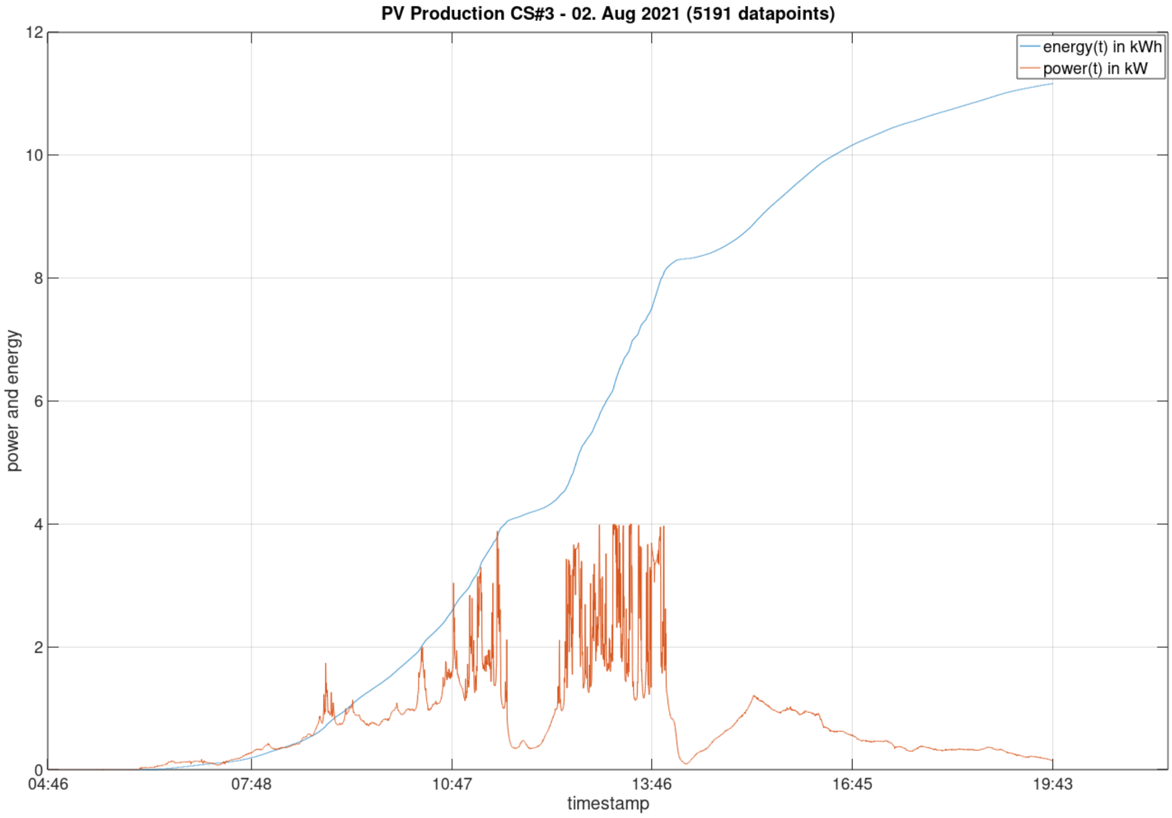
The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

6.2 Overall energy use

In the following the energy drawn from the PV panels is shown. No meters for the company's local electricity grid were involved.

(a) PV-panels: For the GreenCharge@work demonstrator 2 PV systems were available for charging. Figure 10 and 11 show PV production curves for a typical summer day in 08/2021 - blue sky, but still cloudy. The device modules at CS#3 and CS#5 are rated at total peak powers of 4,7 kW and 12,5 kW, respectively. From the 2 graphs it can be seen that the maximum in the respective curves are roughly 20% below these rated peak values. In these examples, electric energy of 11kWh (CS#3) and 23kWh (CS#5) were produced during 02.August 2021 and 01.August 2021, respectively.

(b) Storage battery: Since all efforts failed to integrate the 2 de-installed EV batteries (Na/NiCl2-type, each rated at 24 kWh capacity) into the carport system CS#3, no values for the stored electric energy could be measured. Nevertheless, with its 48 kWh capacity, the size of such type of battery system would have matched perfectly for storing the PV energy produced from the 4,7kWp device during a sunny weekend, when there are no working hours and thus no demand for EV charging expected.



Fig

Figure 10 - Typical day-chart of PV energy production @CS#3 (02.08.2021)

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.

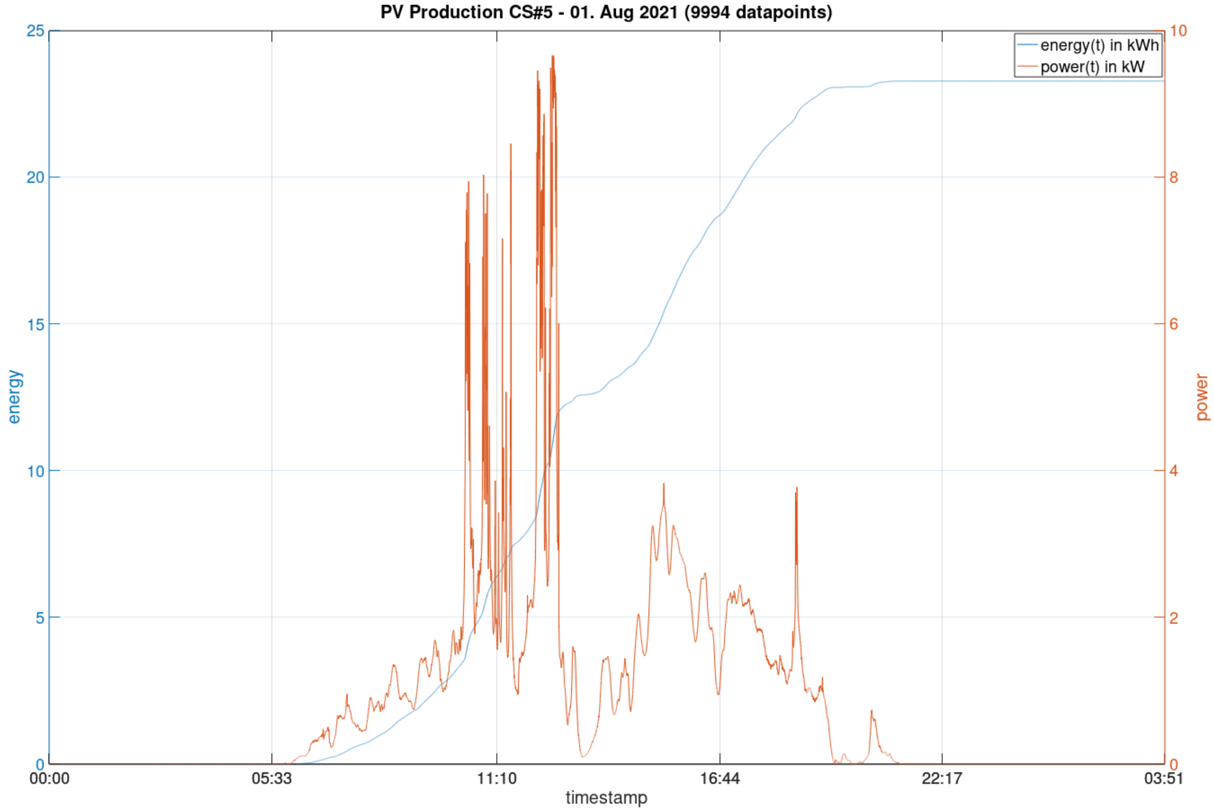


Figure 11 - Typical day chart of PV energy production @CS#5 (01.08.2021)

6.3 Production of green energy

The total amount of photovoltaic energy produced throughout the whole operation phase in the 2 carport stations were derived from the energy counters at the start/end of the operation phase and are given as follows:

CS#3: 3.258,84 kWh

CS#5: 9.023,41 kWh

The ratio of the 2 values (2,77) is reflecting roughly the ratio of the peak power values of the 2 devices (2,66), indicating that the external conditions (e.g., different shadowing effects) for PV energy production from the 2 systems remained unchanged during the demo phase (Aug-Dec 2021).

Figs. 15 and 16 show the power and cumulative electric energy obtained from the 2 PV systems during the first week in August 2021. Here, too, the ratio of the peak powers (2,51) is roughly consistent with the rated peak power ratio.

If we consider a typical commuter, who needs a recharge of 10kWh (for a driving range of about 60km), then at CS#3 the produced PV energy would have been enough for recharging 2 EV each day – in theory. However, as can be seen from the typical charging curves in Figs.8-12, much more energy is drawn from the CP per charging session, namely 30-40 kWh. Of course, this can be counterbalanced using a respectively larger PV device. But it also shows that using the designed storage system in addition to the PV system is exactly the alternate option, at least in principle. Charging this storage overnight at low power and reduced cost (night tarif) and combined with the PV system would provide enough electric energy during the day to supply 2 EVs with even the required 30-40 kWh/day.

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.

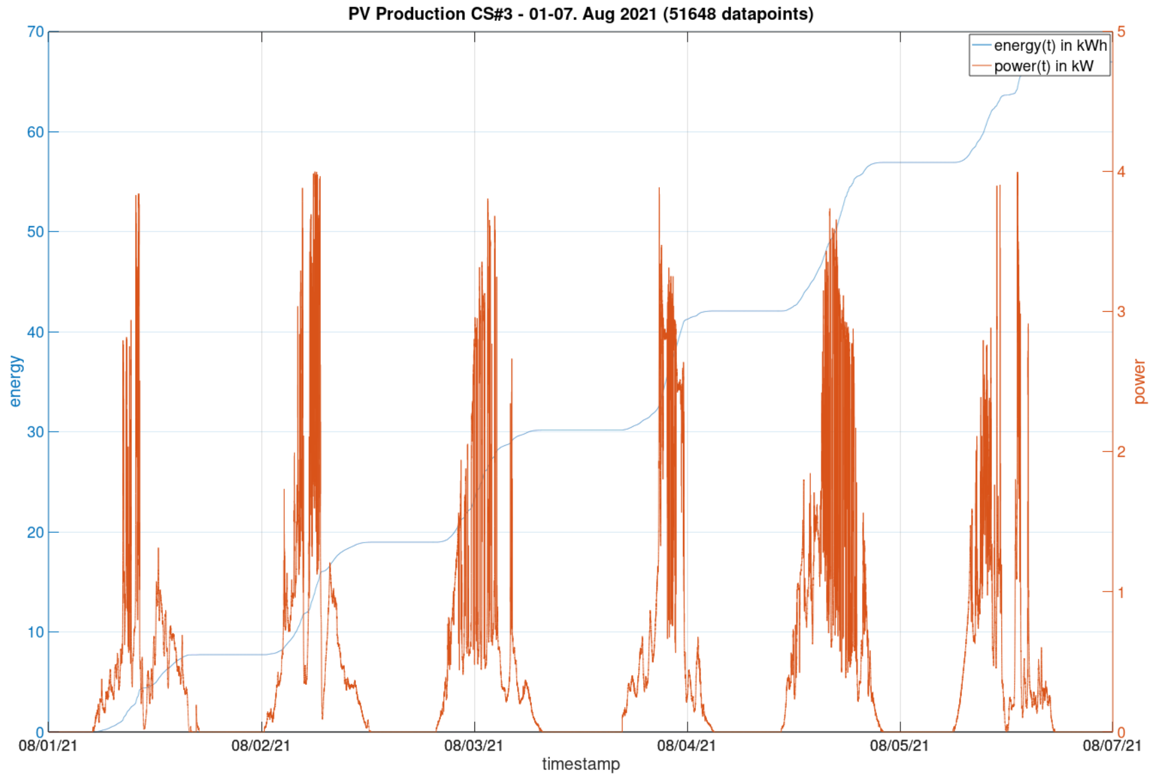


Figure 12 – PV energy production chart from CS#3 (6 days)

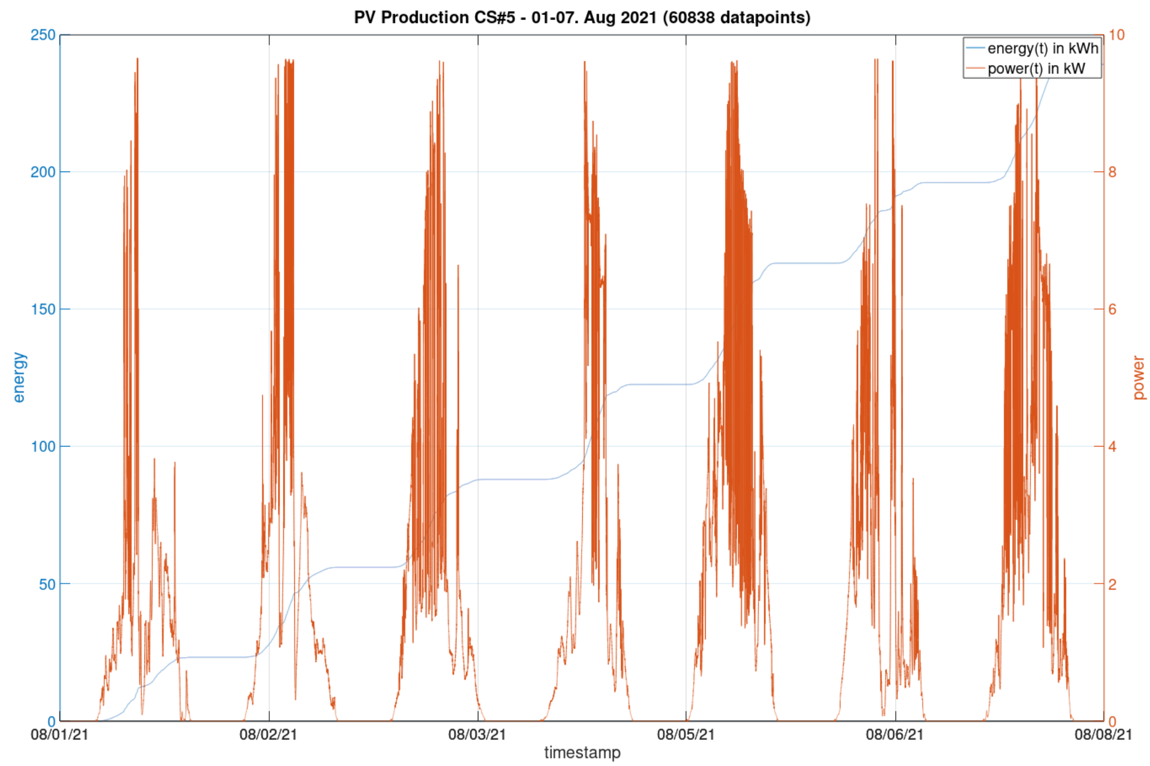


Figure 13 – PV energy production chart from CS#5 (7 days)

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 Smart Energy Management System

In the GreenCharge@work demonstrator a local energy management was installed, namely the gridctrl.aggregator with h/w and s/w implemented, allowing to receive data of both involved charging stations. An "EMS-type" intervention that was made regarded the "limiter": This s/w component ensured that the maximum load on the local company's grid did not exceed a preset value.

No fully operative smart EMS was used as planned during the project phase, because of the lack of stationary energy storage systems. The 2 battery systems demounted from decommissioned EVs received a major defect during implementation and cannot be used any more (CS#3). Further, the RedoxFlow storage system, which was intended as a backup solution, and is integral part of CS#5, received an unrepairable defect after a couple months.

However, in future the EMS will be developed further for such small scale microgrids with a PV/CP system integrated. This system must then be combined with an energy storage system made from decommissioned (2nd-life) lithium-ion EV batteries. This EMS can then be operated cost-effectively in the following way:

(a) Proactive booking a CP (with at least 1 day lead-time) using a web-based solution can be handled by the EMS by reserving full power from the storage battery in addition to the PV supply for the booked charging period. This will be part of the priority charging concept.

(b) The EMS should allocate charging time to the CP only, if large enough power from PV and/or storage battery is available. Otherwise a smooth distribution of grid power over the charging period of time will be provided by the EMS. No costly extra h/w should be installed, since no simultaneous charging with dc-power (PV/storage) and ac-power (grid) is allowed.

(c) The smart EMS must ensure that re-charging the storage system will be done automatically overnight at a reduced tarif in order to provide a fully charged storage system in the morning.

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8 Initial lessons learned of the technical system (summary)

The technical system needs to be evaluated separately for the development phase (Technology prototyping) and the pilot operation phase (Data processing). In the following 2 subsections the initial lessons learned are therefore described separately.

8.1 Technology prototyping

Starting from a manifold of CPs and having experienced a variety of issues of these, the prototyping of technologies finally focused on 2 charging carport stations, both equipped with PV and both promising electric energy storage options (via 2nd-life EV batteries and a redox-flow storage system, respectively). The backend solution via grdctrl aggregator worked properly as well as the additional user frontend (web-based App) for manual data acquisition. Implementation of payment issues was not considered here.

A general issue in the context with using 2nd-life EV batteries 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 producing electric vehicles left the market. As a consequence many details were no longer available that were needed to address the BMS control software of the demounted EV batteries. This was also the case for the employed demounted ZEBRA-Batteries (Na/$NiCl_2$-chemistry). 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.

It is to be expected that repurposing cells from used EV traction accumulators – nowadays Li-ion type in general - will increase dramatically within this decade, when many cars will be decommissioned making the battery system available for a 2nd-life market. Currently, OEM's themselves are already developing concepts to exploit this market by a re-design of the demounted battery systems to build stationary storage systems in the MWh size range. It is to be expected that such systems in the 1MWh range are soon available for charging stations combined with PV and a manyfold of CPs to re-charge, e.g., 10-100 EVs on a company's parking lot or garage.

On the other other hand, the cost of such repurposed EV batteries might be close to prices of systems with new cells built in. A study of the Boston Consulting Group (from 2020) even concluded that due to high cost 2nd-life batteries are no business-case, since a fully automised disassembling process is difficult to achieve by now. Prices might be not far enough below respective storage systems made from brand-new cells.

In any case, standards (interface software and hardware) are needed that are open accessible and well-documented. With these the electronic charge controller of the storage system - Li-ion batteries preferred - can be readily combined to the other components of the charging system.

8.2 Data privacy and anonymization

Data privacy and anonymisation is difficult to achieve, if just a few users are using the technology prototypes (BRE.D1) or the eCarSharing fleet (BRE.D2). Both situations were created by the pandemic, when most commuters worked at home and much fewer booking events were observed than is normally the case.

Large effort was needed to ensure data privacy by uploading research data in an anonymized format only. It turned out that creating the static data-sets manually in the pre-defined format caused a lot of uncertainties and formatting errors. This issue concerned basically the inputs on Makes, Models, Devices, and Entities.

To avoid these issues and provide a human-friendly interface, a new YAML based data-format has been introduced enhancing the readability. It is not too far away from XML-type and data structures in Python and C language. This data-format thus provides a unified device and entity modelling workflow without getting in-touch with CSV data.

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9 Conclusions / Further Work

The Bremen pilot has demonstrated that charge@work is a well-accepted option that should be offered by companies as an incentive to their employees, many of whom are commuting from outside regions.

Remaining issues and perspectives are related to the following topics:

- The proprietary backend solution that has been modified and implemented should be extended to control a multitude of charging stations in a larger surrounding area. Combined with the advanced web-based Application various types of users (business cars, visitors, employees) can be treated individually with respect to their charging needs.
- Integrating/repurposing 2nd-life EV battery: A market on this topic will definitely evolve within this decade and it will be the OEMs that are likely to push it, since they will have access to a high volume of demounted EV batteries. Therefore equipping carport systems with PV and stationary storage in the 1 MWh size range will be a realistic option for companies to shave power peaks at their site during the day and save money by recharging at reduced price (night-tariff) for electricity from the local grid.
- Business case: No business case was exploitable, since in the charge@work demo no payment was involved. Of course, this is going to change after the project phase. However, the acceptance of using the provided CPs depends strongly on the kWh-price: charge@home is the preferred options, if a home-wallbox is available and price of electricity is cheaper there. This is one of the results of the user interviews. For some users, even a PV system is available at home large enough to cover the charging demand of the commuter's EV.

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