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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: D2.20

Technical Monitoring Report and Feedbacks (Barcelona)

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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

This document presents the first outputs obtained from putting into place and running for a period the demonstrators of Barcelona pilot, with special emphasis on the process of data collecting and feedbacks received. The period included extends until end of December 2021, 2 months prior to the finalization of the project.

Barcelona pilot includes 3 different demonstrators: an e-scooter sharing service (BCN.D1), a demonstrator of charging at work with smart energy management (BCN.D2) and a e-bike sharing service for commuters (BCN.D3).

The measures applied to each demonstrator are slightly different, depending on the functionalities of the demonstrator, but all of them have in common the optimal and coordinated use of energy to maximize the use of renewable energy locally produced, and to minimize energy cost and CO2 emissions. The most complete demonstrator in terms of components is BCN.D3 that includes PV panels, an inverter, a stationary battery, sensors to measure energy consumption, production and storage, sensors to monitors e-bike position and its battery status and actuators to control charging process and access to the station with an app.

For the evaluation of the measures in place, a set of Key Performance Indicators (KPIs) have been previously defined. To calculate these KPIs, data from the demonstrators have to be collected, processed and converted into the defined GreenCharge Open Research Data Format.

There are different mechanisms in place for the collection of data, namely, manually, automatically by software applications and through surveys, questionnaires and interviews.

The collection of data, especially the automatic data collection, have been cumbersome since many issues have arisen in interoperability among components and keeping the data flow continuously. Above all, the most challenging aspect has been to get the demonstration in an operative stage producing data. In fact, some of the demonstrators are not fully operative yet. The main reasons for the delays have been organizational problems within stakeholders involved that have jeopardized the communication among partners and progress on the implementation, the COVID-19 pandemic that has caused most employees to work from home, thus not accessing their workplace where the charging points are located, and complexity of the overall solution.

The analysis of the data collected, mainly from BCN.D2 shows that by using a smart energy management system, the charge sessions can be planned to make use of solar energy locally produced. The duration of the charge session is much shorter than the working time, thus some hours of flexibility can be obtained, also to benefit from off-peak energy prices. The production of solar energy on-site is much lower of the energy consumed by the building but serves as a starting point to explore scalability of the PV plant and the potential number of EVs coming in the future.

Additional input has been collected from stakeholders through surveys and interviews. Some of the feedbacks have been used to design the functionalities of the demonstrators. Some additional feedbacks have been used to improve the interaction of the booking app used to reserve a charging spot.

The work remaining until the end of the project includes extending the data set of data collected, calculation of KPIs and formal analysis of the results and completing feedback from users and stakeholders.

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.

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List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
API	Application Programming Interface
BEMS/BMS	Building Energy Management System/Building Management System (In this document, BEMS is chosen to refer either to a BMS either with limited Energy Management functionalities to avoid overlapping with BMS referring to Battery Management Systems)
CMS	Charging Management System
CP	Charging Point
EV	Electric Vehicle
GC	GreenCharge
HVAC	Heating, Ventilation and Air Conditioning
IA	Innovative Action
ICT	Information and Communication Technologies
KPI	Key Performance Indicator
LAN	Local Area Network
NEMS	Neighbourhood Energy Management System
SoC	State of Charge (of a battery)
TSO	Transmission System Operator
UUID	Universal Unique Identifier
UV (Index)	Ultra Violet Radiation

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List of Definitions

Table 2: List of definitions

Definition	Explanation
ETL	It stands for Extract-Transform-Load. It is a set of processes or functions applied to a set of data in order to get the desired records (Extract), format them into the required data format (Transform) and store them into a system or application (Load)

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1 About this Deliverable

1.1 Why would I want to read this deliverable?

The main reason for reading this deliverable is to get insights on the process performed in order to gather data from the pilot that will be used later for evaluation. It covers the period until end of 2021 and the planned activities until the finalisation of the project, in February 2022. Due to some delays in the implementation and operation of the demonstrators, the piloting phase will be extended almost until the end of the project. It is of help for other partners of the consortium to see how the process has gone and to understand where the data comes from. It might be of relevance to learn from experience for other projects or initiatives.

1.2 Intended readership/users

The target audience are members of GreenCharge consortium, especially other pilot participants and the evaluation team.

It might be of interest for the uptake cities members, for Civitas members and for people involved in other projects or initiatives that put in place demonstrators that integrate different systems and need to gather data.

1.3 Other project deliverables that may be of interest

The following deliverable can be useful to read in order to get a complete overview of the development of the Barcelona pilot, the stakeholders and to understand the structure of the data collection process.

- **D2.7 Technical Monitoring Report and Feedbacks (Oslo)** – This deliverable is the sister deliverable with the technical report for Oslo.
- **D2.13 Technical Monitoring Report and Feedbacks (Bremen)** – This deliverable is the sister deliverable with the technical report for Bremen.
- **D2.16 Description of Barcelona Pilot and User Needs** – This deliverable describes the Barcelona pilot in terms of challenges, user needs, use cases, scenarios, stakeholders and locations to be involved and the baseline.
- **D2.17 Implementation Plan for Barcelona Pilot** – this deliverable describes 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.
- **D5.6 Open Research Data** – this deliverable describes the data collected from the pilots and structured for further research on the effects of eMobility in cities according to the Data Management Plan (D1.1)
- **D5.4-D6.3 Intermediate Evaluation Result for Stakeholder Acceptance Analysis** - Describes evaluation results and lessons learned from stakeholder acceptance analysis providing feedback to further refinement of business model designs and technology prototyping.

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2 Pilot description

The pilot site in Barcelona consists of three different demonstrator areas in Barcelona province. An extended description of these demonstrators can be found in *D2.16 Description of Barcelona pilot and user needs*, that was later updated and summarized in *D2.2 Revised Strategic Plan for Pilots*. The summary of the demonstrators follows:

- BCN.D1 – e-scooter sharing service demo (MOTIT)

  MOTIT develops services around e-scooter shared mobility. In particular, it is of interest for GreenCharge the service related to battery hubs and behaviour of users of the e-scooter sharing service. For the first one, MOTIT has several premises, namely kiosks spread over the city where batteries can be gathered to charge them in hubs and act as a selling point of the service. Customers, typically delivery companies, use the e-scooter service per hour and the kiosk tenant takes care of the swapping and charging of the batteries. The goal of this demonstrator is to analyse the charging process of a fleet of e-scooters from the perspective of the fleet operator of the sharing service and estimate flexibility and savings according to variable energy prices. The business model extracted from it is very relevant for the business sustainability. The second aspect to analyse is how an incentive scheme to encourage users to adopt a more sustainable driving profile may help to save energy and span the battery lifetime.

- BCN.D2 - Charging@work demo (EURECAT)
  Eurecat aims at providing a charging service for employees in two of its premises, Cerdanyola and Manresa. The goal of the organization is to use these premises as a proof of concept to extend the service to additional premises according to employees' needs and feasibility. A booking service is in place to get the most of the small number of charging points, while an energy management system will help to use local renewable energy and minimized the impact on the building network and the cost of the energy used for charging.

- BCN.D3 – St. Quirze e-bike sharing demo (ATLANTIS-ENCHUFING-EURECAT)
  The goal was to upgrade the existing e-bike sharing service open to commuters travelling by train to reach the factories spread over a wide industrial area in the town. The introduction of ICT tools enhances traceability of assets, increase security and extract valuable information to extend and improve the service offered to the workers. The deployment of PV panels and a stationary battery, together with a smart energy management allows to charge the e-bikes with green energy locally produced.

2.1 Implemented technologies

A detailed description of the technologies implemented and the planning for testing can be found in *D2.17 Implementation Plan for Barcelona Pilot* and *D2.18 Pilot Component Preparation for Full-scale Pilot (Barcelona)* and *D2.19 Full-Scale Pilot Implementation for Smart Charge and EV Fleet Management*.

In the following sub-sections the updated view of the implementation is presented.

2.1.1 BCN.D1: e-Scooter sharing demonstrator

This demonstrator requires the collection of energy related measurements, mainly consumption of charging sessions, trips characteristics (length, energy used/km, duration) and factors that influences optimal energy management (electricity tariffs and energy carbon footprint). Equipment and software components have been deployed to gather this information as presented in Table 3.

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Table 3: Components in place for BCN.D1

Component	Type	Sub-system	Requirement addressed	GreenCharge impact
Current sensors in battery hub	Hardware	Charging Management System (CMS)	Monitor energy consumption for individual charge session to analyse potential for optimization	Sensors installed in 1 hub
IoT Sensors in e-scooters	Hardware	EV in-vehicle System	Gather information of the trip to extract patterns profiles and improvement when incentives are in place	
MOTIT app	Software	EV in-vehicle System	Provide interaction between service operator, vehicle and user	LITMotit App has been developed specifically for the pilot
Fleet Management Platform	Software	Fleet Management System	Monitor and collect data to be used and analyse in simulations.	Included energy metering of the battery hub.

The components mentioned above produce the data needed for management and evaluation. In the following table we present the type of information generated by each data source.

Table 4: Data sources used by BCN.D1

Data source	Information provided	Observations
Sensors in battery hub	Power delivered to each slot of the battery hub ON/OFF status	CSV files (July 2021 to January 2022) were delivered late and are pending to be processed.
Sensors in e-scooter	For each trip: Kilometres Energy consumed Time duration	CSV files (July 2021 to January 2022) were delivered late and are pending to be processed.
Fleet manager	Charging policy (timeframe to charge the battery)	Data not delivered for analysis.

Data source	Information provided	Observations
Weather service Darksky	Outdoor forecast and actual conditions (temperature, humidity, cloudiness, UV Index)	The service provides actual and forecast information. The exact location can be introduced by the information is generated by interpolation of existing weather stations in the area. It does not provide solar radiation needed to forecast solar energy production, but it provides cloudiness and UV index; it was envisioned to use this data together with the actual radiation captured by the weather station to estimate it using a regressor, but lack of time has prevented it. The data collection is pending, waiting for exact location of the battery hub.
eSios webservice	Spanish Spot prices for energy pool	It provides the spot price at 8 p.m. for the next day. Electricity tariffs in the building are not totally related to the spot price, but it is relevant for simulations. Common information with the rest of the Barcelona demonstrators.
Entso-e webservice	Pan European platform with data of national TSOs. In particular we extract information for the Spanish energy mix for national grid	The information is provided by the Spanish TSO with 1 hour granularity. Forecast energy mix is only provided for Solar and Wind. Common information with the rest of the Barcelona demonstrators.

2.1.2 BCN.D2: Charging in ESN at work Demonstrator

This demonstrator requires the collection of energy related measurements (consumption of charging sessions, consumption of other loads of the building, energy production), context information that influences energy consumption and production (weather conditions) and factors that influences optimal energy management (electricity tariffs and energy carbon footprint). Equipment and software components have been deployed to gather this information as presented in Table 5.

Additional information to gather user's and stakeholders acceptance is required as well, but the mechanisms for such data collection are not described in this section; instead they are handled in section 5.

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Table 5: Components in place for BCN.D2

Component	Type	Sub-system	Requirement addressed	GreenCharge impact
Controllable sockets (Relay)	Hardware	Charging Management System (CMS)	Provide a charging point to employees. Control charging process Keep the investment low (it has been avoided to buy commercial charging points that are more expensive and present interoperability issues)	1 new socket has been installed 2 sockets have been updated adding a control switch and updating wiring
Data Hub/Gateway	Hardware	Charge Management System (CMS) Neighbourhood energy management system (NEMS)	Provide interoperability for energy meters and relays(sockets).	2 gateways deployed linked to charging points. Connect to existing gateways for HVAC and PV+inverter.
Energy meters	Hardware	Charge Management System (CMS) Neighbourhood energy management system (NEMS)	Monitor energy consumption of the main relevant loads for energy management and potential energy billing (in the future). In particular, general electrical consumption of the building, HVAC and charging points.	3 individual energy meters for the charging points have been installed. Extended LAN to enable communication with them.
PV panels	Hardware	Local renewable energy source (LRES)	Minimize organisation carbon footprint	It was already in place. Analysis of data gathered may help to evaluate its performance
Inverter	Hardware	Local renewable energy source (LRES)	Use energy locally produced	It was already in place. A script to gather data with higher granularity using MODBUS protocol has been implemented
Booking system	Software	Charging Management System (CMS)	Manage the sharing of charging points Forecast energy needs	Developed for the project

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eRoaming	Software	Charging Management System (CMS)	Demonstrate interoperability among different project components	Add interoperability with Hubject to the booking system Use ZET app
Optimizer (SEM Scheduler)	Software	Neighbourhood energy management system (NEMS)	Enhance energy management by taking into account energy demand, production, CO2 impact and cost	Tunned for the project. Update interfaces to run as a service and connect to the simulator
Load forecaster (SEM Forecaster)	Software	Neighbourhood energy management system (NEMS)	Enhance energy management by forecasting energy needs (input to SEM Scheduler)	Tunned for the project
Data connectors	Software	Charging Management System (CMS) Neighbourhood energy management system (NEMS)	Enable interoperability among components Gather data for evaluation Provide data in the GC research data format	Developed for the project

The components mentioned above produce the data needed for management and evaluation. In the following table (Table 6) we present the type of information generated by each data source and some observations arisen during the running of the pilot and the collection of data.

Table 6: Data sources used by BCN.D2

Data source	Information provided	Observations
Data Hub/Gateway (1 gateway in Location 1, 1 gateway in Location 2)	Status of the charging points: ON/OFF (2 in Loc1, 1 in Loc2) Energy readings (power, voltage, current) for the charging points (2 in Loc1, 1 in Loc2)	A data connector pulls every minute the status. The service has been disrupted due to several issues, causing the interruption of data gathering, some of them extending several weeks. A Data logger is embedded in the datahub that enables to download information stored locally until it is overwritten
Building Energy Management System (BEMS)	Energy readings (power, voltage, current) for the building loads: HVAC, lighting and the rest of loads (aggregated)	The information for the different loads has not the same granularity. The system has stopped several times and some information is lost.
PV Inverter	Energy readings for PV production (power, voltage)	A data connector pulls data every minute

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Data source	Information provided	Observations
Solar portal for PV Inverter manufacturer	Energy production for the PV panel. Alternate data source to the PV inverter, but with lower granularity and without API for automatic collection	A web-based application enables to download PV production
Weather station	Outdoor current weather conditions (temperature, humidity, solar radiation)	It provides current weather conditions outside the building (on the roof). It does not provide forecasted conditions needed for forecast energy demand and production The system has been interrupted for some periods of time
Weather service Darksky	Outdoor forecast and actual conditions (temperature, humidity, cloudiness, UV Index)	The service provides actual and forecast information. The exact location can be introduced by the information is generated by interpolation of existing weather stations in the area. It does not provide solar radiation needed to forecast solar energy production, but it provides cloudiness and UV index; it was envisioned to use this data together with the actual radiation captured by the weather station to estimate it using a regressor, but lack of time has prevented it.
Booking webapp	Estimated arrival and departure time Estimated energy needs State of Charge at arrival	Information quality relies on the user. For State of Charge, 5 different levels can be provided, that in turns depends on the information to be displayed in the vehicle dashboard.
eSios webservice	Spanish Spot prices for energy pool	It provides the spot price at 8 p.m. for the next day. Electricity tariffs in the building are not totally related to the spot price, but it is relevant for simulations.
Entso-e webservice	Pan European platform with data of national TSOs. In particular we extract information for the Spanish energy mix for national grid	The information is provided by the Spanish TSO with 1 hour granularity. Forecast energy mix is only provided for Solar and Wind.

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2.1.3 BCN.D3: St. Quirze e-bike sharing service Demonstrator

This demonstrator requires the collection of electric energy consumption of charging sessions, energy production of PV panels and energy exchange of the stationary battery, context information that influences production (weather conditions) and factors that influences optimal energy management (electricity tariffs and energy carbon footprint). Equipment and software components have been deployed to gather this information as presented in Table 7.

Additional information to gather user's and stakeholders acceptance is required as well, but the mechanisms for such data collection are not described in this section; instead they are handled in section 5.

Table 7: Components in place for BCN.D3

Component	Type	Sub-system	Requirement addressed	GreenCharge impact
Controllable sockets	Hardware	Charging Management System (CMS)	Control charging process Adapt the existing infrastructure designed for e-bikes, rather than replacing by commercial charging points	5 relays to be controlled remotely have been installed 5 IoT devices with GPRS communications to control relays remotely 5 new charging 'boxes' have been installed that embeds the AC/DC transformer (previously it was external)
Remote control lock (Relay)	Hardware	Charging Management System (CMS)	Enhance security Control access digitally	1 electronic lock installed 1 IoT sensor to control relay remotely (GPRS communications)
Data Hub/Gateway	Hardware	Charge Management System (CMS) Neighbourhood energy management system (NEMS)	Provide interoperability for energy meters and relays(sockets).	1 gateway deployed linked to main meter with MODBUS and GPRS communications.
Energy meters	Hardware	Neighbourhood energy management system (NEMS)	Monitor energy consumption of the charging station for energy management	1 energy meter (MODBUS interface)
PV panels	Hardware	Local renewable energy source (LRES)	Minimize usage of energy coming from the public grid Use of green energy locally produced.	2 PV panels installed on the roof.

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Inverter	Hardware	Local renewable energy source (LRES)	Use energy locally produced (transforms from DC/AC) Control PV, stationary battery and grid energy flows.	1 inverter installed.
Stationary battery	Hardware	Local renewable energy source (LRES)	Intermediate storage to match energy production and demand	1 stationary battery installed 1 IoT device to monitor energy exchange and SoC (CAN communications)
GPS devices	Hardware	EV In-Vehicle System	Monitor position of e-bikes: within boundaries of the operation areas, not stolen Monitor status of the battery	5 IoT devices installed in e-bikes with GPRS communications
eMobility app	Software	EV In-Vehicle System	Monitor usage of the e-bikes Link user with the e-bike, temporary Grant access to the station Provide info to users about trips (km, carbon footprint) Gather feedback from users	Developed for the project
Atlantis backend platform	Software	EV Fleet Management System	Connect field with digital components Monitor the service Store information Enable interoperability between CMMS, NEMS and the EVs	Some adjustments implemented. API developed
Optimizer (SEM Scheduler)	Software	Neighbourhood energy management system (NEMS)	Enhance energy management by taking into account energy demand, production, CO2 impact and cost	Tuned for the project. Update interfaces to run as a service and connect to the simulator Same development as for BCN.D2
Load forecaster (SEM Forecaster)	Software	Neighbourhood energy management system (NEMS)	Enhance energy management by forecasting energy needs (input to SEM Scheduler)	Tuned for the demonstrator to forecast next trips

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Data connectors	Software	Charging Management System (CMS) Neighbourhood energy management system (NEMS)	Enable interoperability among components Gather data for evaluation Provide data in the GC research data format	Developed for the project

The components above mentioned produce the data needed for management and evaluation. In the following table we present the type of information generated by each data source and some observations arisen during the running of the pilot and the collection of data.

Table 8: Data sources used by BCN.D3

Data source	Information provided	Observations
Data Hub/Gateway	Energy readings (power, voltage) for the charging points	A data connector pulls every minute the status. The information is not relevant while charging sessions are not generated. Samples are being generated for test rides.
PV Sensor	Energy readings for PV production (current, voltage)	Not operative since PV are disconnected for safety reasons
IoT device in stationary battery	Energy import/export (current and voltage)	Not operative since PV are disconnected for safety reasons
IoT devices in e-bikes	Position (GPS coordinates), heading, speed, voltage, ignition	Some IoT devices had to replaced (deterioration, voltage incompatibilities)
Weather service Darksky	Outdoor forecast and actual conditions (temperature, humidity, cloudiness, UV Index)	The service provides actual and forecast information. The exact location can be introduced by the information is generated by interpolation of existing weather stations in the area. It does not provide solar radiation needed to forecast solar energy production, but it provides cloudiness and UV index; it was envisioned to use this data together with the actual radiation captured by the weather station to estimate it using a regressor, but lack of time has prevented it.

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Data source	Information provided	Observations
eSios webservice	Spanish Spot prices for energy pool	It provides the spot price at 8 p.m. for the next day. Electricity tariffs in the building are not totally related to the spot price, but it is relevant for simulations. Common information for the 3 Barcelona demonstrators
Entso-e webservice	Pan European platform with data of national TSOs. In particular we extract information for the Spanish energy mix for national grid	The information is provided by the Spanish TSO with 1 hour granularity. Forecast energy mix is only provided for Solar and Wind. Common information for the 3 Barcelona pilot demonstrators

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3 Decided measures and KPI's for Barcelona pilot

3.1 Measures for Barcelona pilot

During the intermediate evaluation process, measures were grouped into measures group to ease understandability, and because the effect of some set of measures could not be decoupled. Thus, here is an updated table of the measures designed for Barcelona demonstrators.

Table 9: Measures for Barcelona pilot

Measure group	Measure	Demonstrator		
		BCN.D1	BCN.D2	BCN.D3
EV Fleet	Shared EVs	X		X
	Shared EVs integrated with public transport			X
Charging	Battery swapping	X		
	Booked charging		X	
	Flexible charging	X	X	X
	Shared CP		X	
	Private CP			X
	Priority access to CP		X	
	Roaming		X**	
Smart Energy Management	Local RES	X*	X	X
	Optimal and Coordinated energy use	X*	X	X
	V2G		X*	
	Local Storage			X
Business aspects	Payment for sharing EV	X		X***
	Rewarding eco-driving	X		

(*) Only as simulation scenarios

(**) As a Proof of Concept

(***) Only informative; no actual money exchanged

3.2 KPIs for Barcelona pilot

The following tables present the details of the KPIs to be evaluated for each demonstrator. The list has been extracted from D5.1-D6.1; additional information, as the specific data source and the corresponding technology component, and the procedure for data collection needed for the KPI calculation as well as the procedure to calculate the KPI combines the information presented in D5.1-D6.1 and D5.4-D6.3.

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Table 10: KPIs for BCN.D1 demo

KPI	Data source	Method data collection	Method for KPI calculation
GC 6.1 Awareness level	Surveys and web metrics	Manual (metrics) Surveys through MOTIT app	Manual Statistical analysis of surveys and qualitative analysis
GC 6.2 Acceptance level	Surveys	Surveys through MOTIT app	Manual Statistical analysis of surveys and qualitative analysis
GC 6.3 Perception level of physical accessibility of service	Interview to service operators	Teleconference	Manual Qualitative analysis
GC 6.4 Operational barriers	Interview to service operators	Teleconference	Manual Qualitative analysis
GC 6.6 Shared EVs per capita	Public reports/DGT database (General Traffic Department)	Manual	Manual
GC 5.1 Number of EVs	Fleet operator platform	Manual	Manual
GC 5.2 Number of charging points	Fleet operator (applies of number of battery hubs)	Manual	Manual
GC 5.3 Utilization of charging points	-Fleet operator platform	Manual format conversion from exported files	Automatic (KPI calculator)
GC 5.5 Charging availability	- Fleet operator platform -battery swapping policy	Manual format conversion from exported files Simulations	Automatic (KPI calculator)
GC 5.13 Charging flexibility	- Fleet operator platform -battery swapping policy)	Simulations	Automatic (KPI calculator)
GC 5.9 Energy mix (green energy share)	-Entso-e for public grid mix -Simulation of LRES	Automatically collected by: -data connectors to Entso-e API -results produced by simulator	Automatic (KPI calculator)
GC 5.10 Peak to average ratio	- Fleet operator platform (base line) -Simulations	Manual format conversion from exported files -results produced by simulator	Automatic (KPI calculator)
GC 5.14 Self-consumption	- Fleet operator platform (base line) -Simulations	Manual format conversion from exported files -results produced by simulator	Automatic (KPI calculator)
GC 5.12 CO2 emissions	- Fleet operator platform (base line) -Entso-e for public grid mix --Simulations of LRES	Manual format conversion from exported files -results produced by simulator	Automatic (KPI calculator)

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.

KPI	Data source	Method data collection	Method for KPI calculation
GC 6.5 Relative cost of the service	-Fleet operator platform -ERP fleet operator	Manual	Manual calculation
GC 5.6 Average operating costs	-Fleet operator platform -ERP fleet operator	Manual	Manual calculation
GC 5.7 Capital investment cost	-ERP fleet operator	Manual	Manual calculation
GC 5.8 Average operating revenues	-Fleet operator platform -ERP fleet operator	Manual	-
GC 5.11 Average charging cost	-Fleet operator platform - Electricity tariffs (eSios API/bills) -Simulations	Manual format conversion from exported files -results produced by simulator	Automatic (KPI calculator)

Table 11: KPIs for BCN.D2 demo

KPI	Data source	Method data collection	Method for KPI calculation
GC 6.1 Awareness level	Surveys and interviews	On-line forms Physical interviews Electronic communication (emails, teleconferences)	Manual Statistical analysis of surveys and qualitative analysis
GC 6.2 Acceptance level	Surveys and interviews	On-line forms Physical interviews Electronic communication (emails, teleconferences)	Manual Statistical analysis of surveys and qualitative analysis
GC 6.3 Perception level of physical accessibility of service	Surveys and interviews	On-line forms Physical interviews Electronic communication (emails, teleconferences)	Manual Statistical analysis of surveys and qualitative analysis
GC 6.4 Operational barriers	Surveys and interviews	On-line forms Physical interviews Electronic communication (emails, teleconferences)	Manual Statistical analysis of surveys and qualitative analysis
GC 5.1 Number of EVs	Survey	On-line form	Manual
GC 5.2 Number of charging points	Site manager	Manual	Manual
GC 5.3 Utilization of charging points	-booking app -Data Hub (energy meter CPs)	Automatically collected by: CMS (EV charging sessions)	Automatic (KPI calculator)

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KPI	Data source	Method data collection	Method for KPI calculation
GC 5.5 Charging availability	-booking app -Data Hub (energy meters CPs)	Automatically collected by: CMS (EV charging sessions) Booking system (reservations)	Automatic (KPI calculator)
GC 5.13 Charging flexibility	-booking app - Data Hub(energy meters CPs)	NEMS CMS (EV charging sessions) Booking system (reservations, SoC)	Automatic (KPI calculator)
GC 5.9 Energy mix (green energy share)	-Entso-e for public grid mix -LRES (PV Inverter) for local grid mix	Automatically collected by: NEMS (data connectors to LRES and Entso-e API)	Automatic (KPI calculator)
GC 5.10 Peak to average ratio	-Data Hub (energy meters CPs) -BEMS (energy meters HVAC and other building loads)	Automatically collected by: NEMS (data connectors to Data Hub and BEMS)	Automatic (KPI calculator)
GC 5.14 Self-consumption	-LRES (PV Inverter) for local solar energy production -BEMS (main electricity meter)	Automatically collected by: NEMS (data connectors to PV Inverter and BEMS)	Automatic (KPI calculator)
GC 5.12 CO2 emissions	-LRES (PV Inverter) for local solar energy production -Entso-e for public grid mix -BEMS (main electricity meter)	Automatically collected by: NEMS (data connectors to PV Inverter and BEMS)	Automatic (KPI calculator)
GC 6.5 Relative cost of the service*	-electricity tariffs for eSios -Data Hub (energy meters CPs) -BEMS (main electricity meter) -LRES (PV production) -average cost of the building -average incomes for an employee	Automatically collected by: NEMS (data connectors to PV Inverter, BEMS, eSios) Manually collected from site manager	Manual calculation
GC 5.6 Average operating costs*	-electricity tariffs for eSios -Data Hub (energy meters CPs) -BEMS (main electricity meter) -LRES (PV production) -estimation of maintenance costs	Automatically collected by: NEMS (data connectors to PV Inverter, BEMS, eSios) Manually collected from site manager	Manual calculation
GC 5.7 Capital investment cost*	-Cost of resources	Manually defined	Manual calculation
GC 5.8 Average operating revenues*	NA	-	-

(*) As there is no real money exchange, the business model KPIs are not relevant for this demonstrator and their calculation has been dropped.

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Table 12: KPIs for BCN.D3 demo

KPI	Data source	Method data collection	Method for KPI calculation
GC 6.1 Awareness level	Surveys	On-line forms Link in the app	Manual Statistical analysis of surveys and qualitative analysis
GC 6.2 Acceptance level	Surveys	On-line forms Link in the app	Manual Statistical analysis of surveys and qualitative analysis
GC 6.3 Perception level of physical accessibility of service	Surveys	On-line forms Link in the app	Manual Statistical analysis of surveys and qualitative analysis
GC 6.4 Operational barriers	Surveys	On-line forms Link in the app	Manual Statistical analysis of surveys and qualitative analysis
GC-6.6 Shared EVs per capita	Statistics on commuters/employees of the companies that have access to the service	Manual	Manual
GC 5.1 Number of EVs	Site manager information	Manual	Manual
GC 5.2 Number of charging points	Site manager information	Manual	Manual
GC 5.3 Utilization of charging points	-Data Hub (energy meters CPs) -CMS	Automatically collected by: CMS (EV charging sessions) NEMS (energy consumption)	Automatic (KPI calculator)
GC 5.5 Charging availability	-CMS -Data Hub (energy meters CPs) -Atlantis fleet platform (trips, SoC)	NEMS (energy availability) CMS (EV charging sessions) Mobility patterns (when the bikes are in the station and when away)	Automatic (KPI calculator)
GC 5.13 Charging flexibility • EV models • Individual EVs • Individual Charge points • Metadata on reservation/booking events EV charging/ discharging sessions	-CMS -Data Hub (energy meters CPs, main meter) -Atlantis fleet platform (trips, SoC)	NEMS (energy availability) CMS (EV charging sessions) Mobility patterns (trips length) SoC of batteries and estimation of kWh/km	Automatic (KPI calculator)
GC 5.9 Energy mix (green share)	-Entso-e for public grid mix -Data Hub (PV sensor, main meter) -Atlantis fleet platform (IoT stationary battery)	Automatically collected by: NEMS (data connectors to LRES, Entso-e API, Atlantis API)	Automatic (KPI calculator)

KPI	Data source	Method data collection	Method for KPI calculation
GC 5.10 Peak to average ratio	-LRES (PV Inverter) for local solar energy production -Data Hub (main electricity meter, CP meters) - Atlantis fleet platform (IoT stationary battery)	Automatically collected by: NEMS (data connectors to PV, stationary battery, main meter)	Automatic (KPI calculator)
GC 5.14 Self-consumption	-LRES (PV Inverter) for local solar energy production	Automatically collected by: NEMS (data connectors to PV sensor)	Automatic (KPI calculator)
GC 5.12 CO2 emissions	-LRES (PV Inverter) for local solar energy production -Entso-e for public grid mix -Data Hub (main electricity meter)	Automatically collected by: NEMS (data connectors to PV sensor, electricity meter, eSios)	Automatic (KPI calculator)
GC 6.5 Relative cost of the service	NA (it is free of charge)	-	-
GC 5.6 Average operating costs (*)	-electricity tariffs for eSios -Data Hub (main meter) -LRES (PV production) -estimation of operation & maintenance costs	Manually defined	Manual calculation
GC 5.7 Capital investment cost (*)	-Cost of resources	Manual	Manual calculation
GC 5.8 Average operating revenues	NA (No revenues)	-	-
GC 5.11 Average charging cost (*)	-electricity tariffs for eSios -Data Hub (main meter) -LRES (PV production)	Automatically collected by: NEMS (data connectors to PV sensor, electricity meter, eSios)	Manual calculation

(*) As there is no real money exchange, the business model KPIs are not relevant for this demonstrator and their calculation has been reconsidered.

3.3 Data collected by SW according to the research data document

As presented before, some data is collected manually and some data is collected automatically by one of the technology components. This latter type of data is referred as logfiles in the document D5.6 Open Research Data. Data formats of all data entities, including logfiles have been established in advance to be able to develop ETL processes or scripts to transform information from the internal data model in the different systems to the so called GreenCharge research data format. The progress on data collection for each demonstrator has been followed up within the bi-weekly evaluation task force meetings and registered in an internal document.

At the moment of writing this report some data is still not collected or not transformed into the GreenCharge research data format. The following table present the details for each demo.

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Table 13: Summary of data collected by software in Barcelona demonstrators

Demo	Type of record	Provider	Time period	LogFiles	Observations
BCN.D1	Trips	MOTIT	-BCN 20-07-2021 to 31-12-2021 LaCoruña 02-10-2020 to 31-01-2022	BCN every 5 minutes LaCoruña: per trip-	This kind of information is not part of the GreenCharge research data but it is useful to set some simulation scenarios based on mobility patterns.
	Reservation/Bookings	MOTIT to provide raw data Eurecat to translate into GC format	-	0	In GC bookings refer to booking of the charging point. In the case of MOTIT, the bookings refer to reservation of trips; e-scooters cannot be charged while they are being used. However the transformation to booking of charging time slot is too complicated, so it has been dropped. Besides, e-scooters are not booked in advanced anymore.
	EV charging sessions	MOTIT to provide raw data Eurecat to translate into GC format	BCN 20-07-2021 to 31-01-2022	BCN every 5 minutes	Raw data has still not been provided. The amount of information generated is quite low.
	Energy import/export	MOTIT to provide raw data Eurecat to translate into GC format	-	0	Raw data has still not been provided. The amount of information generated is quite low
	Average grid mix in public grid	Eurecat (same data for the 3 pilot sites, (see BCN.D2)	(see BCN.D2)	0	No logfiles for this demonstrator have been generated yet because they will be tailored according to the energy import/export period
	Variable energy cost in public grid	MOTIT to provide electricity tariffs Eurecat to translate into GC format	-	0	Information about spot prices for simulations can be copied from BCN.D2
	Predicted weather data	MOTIT to provide exact location Eurecat to collect data from Darksky weather service	-	0	No logfiles for this demonstrator have been generated yet because they will be tailored according to the energy import/export period
	Measured weather data	MOTIT to provide exact location Eurecat to collect data from Darksky weather service	-	0	No logfiles for this demonstrator have been generated yet because they will be tailored according to the energy import/export period

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Demo	Type of record	Provider	Time period	LogFiles	Observations
	Sensor data (energy readings)	MOTIT to provide raw data Eurecat to translate into GC format	-	0	Raw data has still not been provided. The amount of information generated is quite low
BCN.D2	Reservation/Bookings	EURECAT (via booking reservation system)	-	0	No booking sessions available yet. To build the baseline, a period with no booking was foreseen. Lock down and mandatory teleworking periods have limited the options to get users to use the booking app. Attempts to get some booking sessions before the evaluation process is finished
	EV charging sessions	EURECAT (via charging management system)	July 2020 – January 2022	Logfile per charging session 1-minute granularity	Logfiles format and consistency being checked
	Heating/cooling sessions	EURECAT (via BEMS)	January 2020-January 2022	Logfile per day 5-minute granularity	Logfiles format and consistency being checked Some long periods with missing data
	Solar plant sessions	EURECAT (via NEMS/inverter solar portal)	January 2020-January 2022	Logfile per day 15-minute granularity*	Logfiles format and consistency being checked (*) 1-minute resolution data is available only for very short periods.
	Energy import and export	EURECAT (via BEMS)	January 2020-January 2022	Logfile per day 1-minute granularity	Logfiles format and consistency being checked Some long periods with missing data
	Average grid mix in public grid	EURECAT (via Entso-e API)	January 2020-January 2022	Logfile per day Hourly granularity	Logfiles format and consistency being checked
	Variable energy cost in public grid	EURECAT (via eSios API and energy bills)	January 2020-January 2022	Logfile per day Hourly granularity	Under construction Scheme tariffs changed in June 2021
	Predicted weather data	EURECAT (via Darksky API)	January 2020-January 2022	Logfile per day Hourly granularity	Logfiles format and consistency being checked Forecasted solar irradiation not available; working on deducing it from cloudiness

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Demo	Type of record	Provider	Time period	LogFiles	Observations
	Measured weather data	EURECAT Darksky API on-site weather station)	 January 2020-January 2022 March 2021-January 20222	Logfile per day and location Hourly granularity 1 minute granularity	Logfiles format and consistency being checked
	Sensor data (CP energy meters)	EURECAT (via Data Hub)	July 2020 – January 2022	Logfile per day and location 1 minute granularity	Logfiles format and consistency being checked Some gaps observed Logs for CP in LOC2 only available from December 2021
BCN.D3	EV Charging sessions	EURECAT (via Data Hub)	-	0	Test samples being generated Demonstrator not in operation
	Solar plant sessions	EURECAT (via Data Hub)	-	A logfile per day 1-minute granularity	Under construction
	Battery sessions	EURECAT (via Atlantis API)	-	A logfile per day 1 minute granularity	Test samples being generated Demonstrator not in operation
	Energy import and export	EURECAT (via Data Hub)	-	A logfile per day 1 minute granularity	Test samples being generated Demonstrator not in operation
	Variable energy cost in public grid	EURECAT (via eSios API)	(see BCN.D2)	Logfile per day Hourly granularity	Under construction
	Predicted weather data	EURECAT (via Darksky API)	(see BCN.D2)	Logfile per day Hourly granularity	Forecasted solar irradiation not available; working on deducing it from cloudiness Period will be adjusted according to import and export data
	Measured weather data	EURECAT (via Darksky API)	(see BCN.D2)	Logfile per day Hourly granularity	Measured solar irradiation not available; working on deducing it from cloudiness Period will be adjusted according to import and export data
	Sensor data (IoT geotrackers)	EURECAT (via Atlantis API)	-	Logfile per day and per e-bike 1 minute granularity	Test samples being generated Demonstrator not in operation

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4 Description of collected data

4.1 Description of the process of data collection

Basically, there are three different methods of data collection:

- Manually: The data is extracted from whatever database, document or system in a manual manner and the information is typed into text files with the GC research data format.
- Automatically: The text files with the GC research data format are generated automatically by a script run periodically (or on demand) that queries the data base for a specific time period and time series and converts them into the GC format.
- Hybrid: The data is stored in a legacy system that does not provide any API for automatic data extraction, only exportation of data, typically in csv format is possible. In this case, the exportation is done manually, and a script process the csv file and apply corresponding transformations to generate an output file in GC research data format.

The research data set is composed by three different types of data, as described in D5.6 Open Research Data namely:

- Device models
- Individual devices
- Logfiles

Device models and individual devices need to be generated only once, unless any equipment or component change during the demonstration phase. By contrast, logfiles are typically generated periodically, although some batch process can be run to generate them for a specific time period.

Following there is a summary of the methods used to collect data in the three demonstrators

Table 14: Summary of the data collection methods for Barcelona demos

Category	Type of data	Collection method		
		BCN.D1	BCN.D2	BCN.D3
Device models	Heating/Cooling devices	NA	Manual	NA
	PV panels	NA	Manual	Manual
	Stationary Batteries	NA	NA	Manual
	Inverters	NA	Manual	Manual
	Sensors	Manual	Manual	Manual
	EVs	Manual	Manual	Manual
Individual devices	Individual software systems	Manual	Manual	Manual
	Locations	Manual	Manual	Manual
	Heating/cooling devices	NA	Manual	NA
	Solar plants	NA	Manual	Manual
	Stationary batteries	NA	NA	Manual
	Sensors	Manual	Manual	Manual
	EVs	Manual	Manual	Manual

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	Charge points	NA	Manual	Manual
	Energy meters	Manual	Manual	Manual
	Price list	Manual	Manual	Manual
	Tariff scheme	Manual	Manual	Manual
Logfiles	Booking sessions	NA	Auto	NA
	Charging sessions	Hybrid	Auto	Auto
	Heating/Cooling sessions	NA	Auto	NA
	Solar plant sessions	NA	Auto/Hybrid	Auto
	Stationary battery sessions	NA	NA	Auto
	Energy import-export	Hybrid	Auto	Auto
	Energy mix in the public grid sessions	Auto	Auto	Auto
	Variable energy cost in public grid	Auto	Auto	Auto
	Predicted weather sessions	Auto	Auto	Auto
	Measured weather sessions	Auto	Auto	Auto
	Sensor data (IoT geotrackers)	Hybrid	Auto	Auto

Eurecat, as data site manager has taken care of the gathering the information of the demonstrators with the support of the rest of partners involved, namely ATLANTIS, ENCHUFING and MOTIT.

For the data collected manual the process is as follows:

1. Request data to component owners
2. Anonymised data (if required, see section 4.4)
3. Type the file with the information in the GC research data format
4. Upload the file to the SFTP server

For the automatically collected data:

0. Develop the script to extract information from the data source (internal database)
1. Run the script to transform the internal data model into the GC research data model, periodically or on demand for batch data generation
2. Upload the files to the SFTP server (originally it was planned to upload it automatically, but so far it has done manually)

For hybrid process data collection:

0. Develop the script to transform information in csv format into the GC research data model
1. Request data to component owner or perform data extraction directly
2. Run the script on demand to apply transformation until GC research data model is achieved
3. Upload the files to the SFTP server

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4.2 Description of challenges regarding data collection

The main challenges encountered are listed below, in severity order

1. Lack of data coming from the demonstrators
2. Difficulties in keeping data gathering 24/7
3. Communication with stakeholders
4. Discontinuity of the demonstrators
5. Interoperability among systems/components
6. Transformation into GC research data format

In the following subsections they are explained in more detail.

4.2.1 Lack of data

It has been extremely challenging to put the demonstrators into operation. In fact, one of them is not yet operational at the time of writing this report. That has caused that the processes of data transformation and syntax checking has been delayed affecting evaluation activities.

Once in operation, the data regarding booking and charging sessions, that is the most relevant to see the differences before and after GreenCharge, has come very rarely. The reason is the low number of users of the demonstrators and the mobility measures imposed by COVID19 pandemic.

In the case of BCN.D1, MOTIT faced some organisational problems and its viability was compromised. As a result, the business model was changed and this affected as well as the demonstrator itself. Putting everything in operation was slower than expected. Besides, the number of EV actually in operation and the number of services is low.

In the case of BCN.D2, the 'home working' policy was put in place in March'2020. For some periods, when the conditions improved, some employees when to the offices. A hybrid plan to work some days a week in the office and some days at home was supposed to be put in place in December'2021, but in November'2021 the pandemic situation went worse than ever and now only very few employees are allowed to go to the offices. The situation will not change before the end of the project. Besides, the number of EV drivers is quite low.

In the case of BCN.D3, the number of e-bikes is very low as well, but we still do not know what the usage will be. In this case the issue has been that it is not yet in operation. There are several reasons for the delay. First, the lockdown, then the communication with the townhall was interrupted, and now we are facing the slowness of bureaucracy to get the terms and conditions approved. The issue with the communication will be detailed in section 4.2.3.

4.2.2 Continuous data flow

The second big challenge has been to keep the data collecting process running in a continuous way. The processes had stopped for a myriad of reasons. That has caused that the time series for the different variables of interest present gaps, some of them several weeks, or even months, long. The reasons are not unique. For instance, in the case of BCN.D2 the problems arose from a restructuring of the internal LAN, for the expiration of the license of the BEMS, for debugging logs filling up the disk space, for electrical cuts that did not trigger the process again, for changes in the API of eSios, and so on.

To mitigate these effects some notifications have been implemented, send to a MS Teams channel, but still sometimes reaction time to address the issue is quite long.

4.2.3 Communication with stakeholders

Regarding this challenge, we can find two different types of stakeholders, those belonging to the GC consortium, and external stakeholders that had not signed the consortium agreement and do not receive any funding for their participation.

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In the first case, for some periods the communication had not been fluent enough, for instance because the company was struggling to survive and to get back on its feet was of highest priority.

In the second case, it is of special relevance the case of external stakeholders involved in BCN.D3. The first contact person was very enthusiastic and things were progressing well. Unfortunately, this person left the entity and it took more than a year, in the worst of the pandemic, to recruit a replacement. Besides, the new person was overwhelmed with the job not done for a year, did not have the background of the demonstrators, and was sceptic about the usefulness of implementing the demonstrator. Although all the stakeholders had signed an agreement prior to GreenCharge for the implementation and operation of the service, it was difficult or unadvisable to reach the point to pursue legal actions for not performing as expected. At the moment of writing this document, the only step missing is the authorization of the terms and conditions, but unfortunately, there is not much time left within the project timeframe to gather significant data usage and real users feedback.

Finally, although the impact has been a way less important, the changes in the researchers and developer teams, in particular at Eurecat, has caused some inefficiencies in the hand-over and fixing problems that arose after more than a year of implementation.

In general, this project was about putting different systems to communicate each other, but sometimes communicating among people is also a handicap.

4.2.4 Discontinuity in the demonstrators

A side effect of the pandemic was that services and offices were close or with a reduced activity. That has caused that the demonstrators, in particular, the e-bike station of BCN.D3 looked abandoned and has suffered from vandalism. To amend it, partners had to replace some equipment, enhance control access security and make the e-bikes repaired (flat tires, breaks, …). Yet, some IoT sensors had to be changed because electronic components shortage has affected the designed circuitry to exchange battery information.

The case of BCN.D2 has been less severe, but still when nobody uses an installation, it takes time to realise that a component is not working, and it takes time to fix it.

4.2.5 Interoperability among systems

In fact, in an IA, interoperability and integration of systems should have been the first challenge. In fact, it has been a challenge, but it has been possible to solve technical with more or less effort. To avoid interoperability problems of commercial systems, most of the systems deployed, especially those meant to collect data, has been developed by partners using commercial sensors and open electronics.

However, still some issues have appeared in this sense. It is worth to mention the cumbersome process to get data from the e-bike batteries using CAN protocol, and the test-error process to get the information from the inverter in BCN.D2 using MODBUS. Although the specification of the bits/bytes of these two protocols is well-established, the coding of the information is left to the device manufacturer and they can choose to send power in kW or W, decimal values or convert them to integer, put the voltage in the first register or in the register number 32, and so on. Documentation is not always clear or easy to access. However, after several attempts, we succeed.

Another example is the use of third-party APIs that can change over time without notice. In the case of eSios API to get information about spot electricity prices, due to regulation changes in the electricity tariffs established by government, the information that was relevant for GreenCharge was shifted to another id. It took some time to realise that we were getting empty records. The data connector to retrieve this information had to be modified and on-demand request to recover missing data had been performed. In the case of Darksky to get weather information, the service provider decided to discontinue the service by August 2020. Luckily for us, they reconsider their decision and the API will be accessible until December 2022. Although this will prevent to use this data connector for future projects, it will allow to finalise this project with no further problems.

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4.2.6 Transformation into GC research data format

The definition of the GC research data model has been complex. In order to reach a general framework that might be useful in multiple scenarios, several iterations had been necessary, and as a result of an iteration, changes in the format were proposed. This fact has not been perceived as a major challenge, and it is the natural development path. Bi-weekly meetings of the evaluation task force, interaction among developers and goodwill has solved syntax errors caused my misinterpretation of specific fields or by bugs in the source code.

The only thing that has been challenging in this regard is that this process is time consuming and has come very late in the project, when the data has been started to flow, and overlapping with many other activities in the project.

4.3 Data quality assurance

The process for data quality assurance has two paths.

- Visual inspection
- Automatic data cleansing

The visual inspection has been performed using grafana[1], an open-source tool that allows inspection of data stored in a database. It supports many database formats. In particular, we store time series in an Influx database. Figure 4-1 shows an example of a dashboard to visualize a group of variables. It is quite convenient because the time period can be changed at any time and the chart allows pan and zoom. This first observation helps to identify the most frequent data errors.

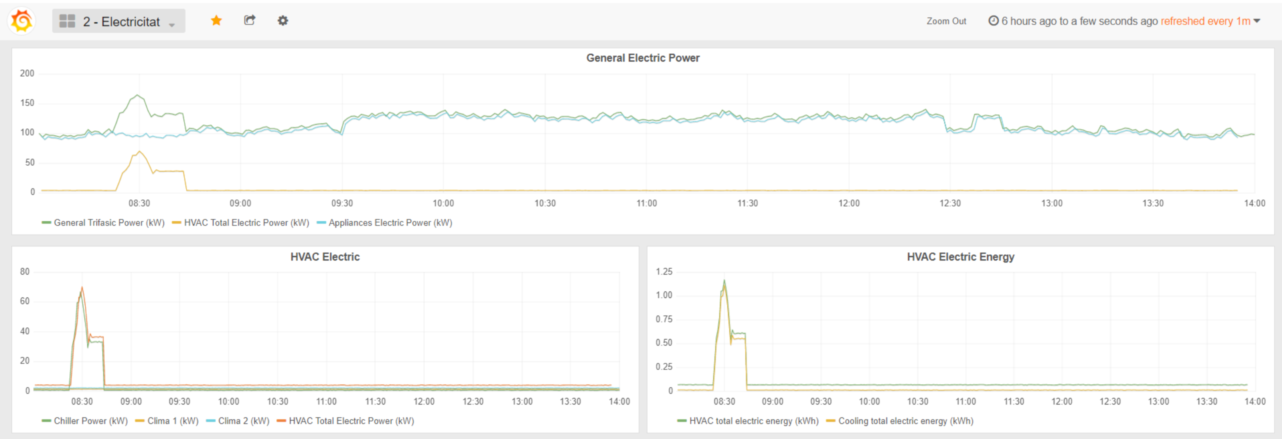

Figure 4-1: Dashboard to inspect data quality

The second process takes place automatically, as data is collected and before storing them in the database. A process performs basic filtering for outliers detection and populates small gaps. The filtering detects values that are out of a pre-configured range. The most common error is to receive 0 or a constant value. There are not trivial to filter, since 0 is a valid value; that is why the visual inspection is also done. Missing values is the most common issue. When the gap is small, saying 1 to 3 samples, the gap is populated with values obtained by linear interpolation. For big gaps, no actions are taken. In the future, they can be populated using a forecast algorithm, but it has been left out of the scope of the project.

[1] https://grafana.com/

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4.4 Data processing

Due to the fact that the data collected will be made publicly available, it has to be assured that no personal data is released. Following the guidelines of the Data Management Plan (described in D1.1), some pieces of information have been anonymised. The process has been applied to the following entities:

- EV models: The individual EVs do not relate to commercial brands and models. A common EV models database has been created within the project that links the actual EV brand and model with an UUID. An online tool has been used to generate this UUID. This database is maintained by the project and is not published. Therefore, when a charging session is recorded for a certain car, the model associated to that car is not known. Instead, a UUID is presented that enables to obtain the characteristics of this vehicle, mainly the battery capacity. This precaution is necessary because the number of EVs in the demonstrators is low and it might be possible to link an EV to the user through the model of the vehicle.
- Pilots, demos and locations are designated as P, D, L and a numbering. The link with the physical location is not present.
- Individual entities: IDs are UUIDs. The intention is to avoid using the actual utility energy meter id, or the number that appears in the physical charging point, or any coding that could make easy to link the actual device with the digital entity.

The table that links the internal id's with the UUIDs published in the open research data is kept in a file in server at Eurecat. The server has access control and can be accessed only from the intranet and the file itself is encrypted.

Besides, data coming from MOTIT platform and Atlantis platform refers to id's that don't have a meaning outside these platforms. The link with the actual vehicle or user is not known by Eurecat.

In order to generate the files in the GC open research format, scripts in Python have been developed. The scripts query the tables in the database and produce the files. The database structure for BCN.D2 and BCN.D3 is the same, in order to facilitate re-usability of the scripts. The scripts were supposed to run automatically, but at the moment of writing this report they run on demand since the quality checker and syntax checker is still on going.

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

Apart from the data coming from “machines”, the project is also interested in the acceptance of the stakeholders, from users to operators and developers. This information is gathered using other mechanisms, mainly surveys, questionnaires and interviews. They are well described in D5.1-D6.1 Evaluation Design - Stakeholders Acceptance Evaluation Plan, and D6.2 Data Collection and Evaluation Tools.

From the point of view of the project, it was important to collect feedback before and after GreenCharge measures were applied. The feedback gathered before measures is reported in D5.4-D6.3 Intermediate Evaluation Results. A final round is to be performed to gather the last impressions of GreenCharge users and stakeholders that will be analysed in D5.5-D6.4 Final Evaluation Results

This is a summary of the actions done to collect stakeholders’ opinions for Barcelona pilot.

Action	Purpose	When	Who	Feedback
Round to Local Reference Group (1) Interview (face-to-face) to energy and mobility Institute	Get feedback on their vision about roadmap, barriers, regulation and links to relevant stakeholders	2018-10-09	ICAEN (regional public authority) EURECAT	Policies on deployment of charging infrastructure: Slow charging points at home or work; regulation to ease the installation in community garages. Fast charging points only for emergency charging in cities and in main roads/highways Subsidies for infrastructure, but free charging is not sustainable.
Round to Local Reference Group (2) Interview (teleconference) to Barcelona Metropolitan Area entity	Get feedback on their vision about roadmap, barriers, regulation and links to relevant stakeholders	2018-10-17	ATM EURECAT	Need to make charging points interoperable Booking of charging points is a burden (charging points booked and not used, users disappointment, charging sessions longer than expected,…) Reliability of charging points, many deployed in Barcelona city that are not working Open to share data of charging sessions
Potential target for GC solutions (1) Interview (teleconference) a car sharing operator in a medium-size city	See if they can participate in any of Barcelona use cases (replicability)	2018-10-24	Car sharing company EURECAT	Very small company and in a very early stage to get involved in research/innovation. Their approach was first to get it running and then to improve it. GreenCharge solution seemed far away in their roadmap
Business Workshop Round 1 Barcelona + Local Reference Group	Generate a baseline for business models to ensure a clear insight in the local possibilities and the starting position of the different urban living labs	2018-11-27	PNO, EURECAT, ATLANTIS, MOTIT, ENCHUFING, SINTEF , LRG (local and regional public authorities, automotive club, charging station installer)	Check opportunities to brand green energy usage (e-scooter sharing) Conflicting interests between collective transport policies and private sharing companies (use of public space) Safety aspects of charging infrastructure (obstacles in public space)

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Action	Purpose	When	Who	Feedback
Round to Local Reference Group (3) Interview (face-to-face) to a water utility that has some EV in their fleet and some charging points	Explore their needs and interest in testing some of GreenCharge components (replicability) To expand the potential users and stakeholders minimize the risk of a low EV penetration. Access to data helps the evaluation process	2019-03-19	Regional water utility EURECAT ATLANTIS	Interested in branding their sustainability commitment. Open corporate charging points to public. Small potential to do smart charging on their corporate vehicles (policy: always charge for emergencies)
Design of BCN.D3 (1) Meeting (face-to-face) with St, Quirze townhall	Understand current operation of the e-bike sharing service and how GC proposition could improve it	2019-04-05	St. Quirze townhall representative EURECAT ENCHUFING ATLANTIS	The service is well-accepted Some issues with users changing the bikes Possibly rides out of the town borders Appreciate to have more control
Potential target for GC solutions (2) Interview (face-to-face) with a larger automotive club	Explore interest in participation in the project as a demonstrator with its EV fleet (replicability)	2019-04-10	Automotive Club representatives EURECAT ATLANTIS	First priority to have the service vehicles charged Some room to test smart charging in e-motorbikes of the corporate fleet Uncertainty on the work to be done in the electric installation
Potential target for GC solutions (3) Interview (face-to-face) with a car renting operator in Barcelona	Explore interest in participation in the project as a demonstrator with its EV fleet (replicability)	2019-04-26	Car rental manager EURECAT ATLANTIS	Very interested in having an app for reservation of the vehicles No interest in shifting to eMobility; users were demanding a car not an electric car.
On-line survey to BCN.D3 users	Gather baseline before GC measures Insights on their satisfaction on the current state of the service and identify needs to be covered by GC	2019-05-31	e-bike sharing users EURECAT	Interest in green charging No interest in route planners They wish there were more e-bikes Better maintenance of the e-bikes
On-line survey to BCN.D2 potential users	Identify users with an EV	March 2020	EURECAT	Only few replies Some users already identified word of mouth Happy to have the opportunity to charge in the premises
Short interviews to BCN.D2 users	Collect impressions on the solution deployed and identify needs	July-October 2021	EURECAT	Happy with the charging options Less usage than expected because of home-office policy The sharing concept has not been demonstrated because of as charging points as users.

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Action	Purpose	When	Who	Feedback
Interview (teleconference) to a MOTIT partner managing e-scooters	Collect impressions on GC proposition and if it is relevant for their business	October-2021	MOTIT ally EURECAT	GC proposition is aligned with their interests
On-line survey to BCN.D2 users and not users	Identify employees mobility patterns and future EV drivers and users of the charging infrastructure	Desembre-2021	EURECAT	Few replies (25) EVs are seen as too expensive Many don't have options to install charging infrastructure at home EV drivers are happy with the charging points and they will use them if they go to the office
Focus group implementation & operation BCN.D3	Collect experiences of involved partners and lessons learnt	Planned: 2022-02-01	ATLANTIS ENCHUFING EURECAT	
Focus group implementation& operation BCN.D3	Collect experiences of involved partners and lessons learnt	Pending	MOTIT EURECAT	

After March 2020, most of the feedback has been collected by digital means, using on-line surveys or teleconferences due to the pandemic. However, prior to that, we tried to organise a Focus Group addressed to BCN.D3 potential users (actual users of the e-bike sharing service) and it had to be cancelled for low attendance. A big issue is to ask people to go to a place and spend a couple of hours of their time in exchange of the promise that their opinions will be taken into account. That seems to be not a reward attractive enough. Surveys have not been more successful either, and the participation has been disappointingly low even when they could complete it at any time, on-line. Above all, the major challenge have been to find EV users; they are still a minority in our region (Barcelona and surrounding area).

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6 Monitored data

In the following subsections, a sample of the data gathered during the demonstrations activities is presented in order to provide a gist of the patterns observed. A deeper analysis will be presented in D2.21 Final Report for Barcelona Pilot – Lessons Learned and D5.5-D6.4 Final Evaluation Results.

6.1 EV charging

For a period of relative high activity in BCN.D2, when pandemic situation allowed some days of work in the offices, the amount of energy used in charging sessions is at most 100 kWh for the whole month, as presented in .

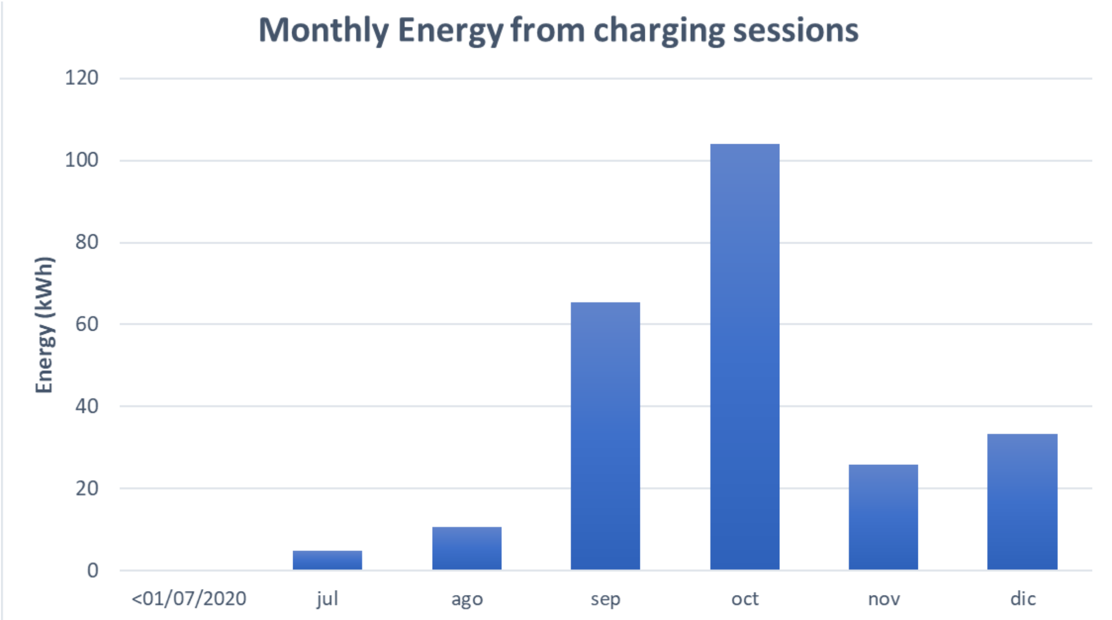

Figure 6-1 Monthly energy consumed by charge sessions in BCN.D2

A charging session typically lasts 3 hours while employees used to stay in the premises for 7-8 hours minimum. Also it has to be taken into account that the active users drive hybrid EVs, with smaller battery capacities compare to that of Full EVs. In case of several users willing to charge, they can be served in a sequential order. In summer, the arrival of the employee overlaps with the starting of generation of solar energy, thus the charging session can start in few time after arrival.

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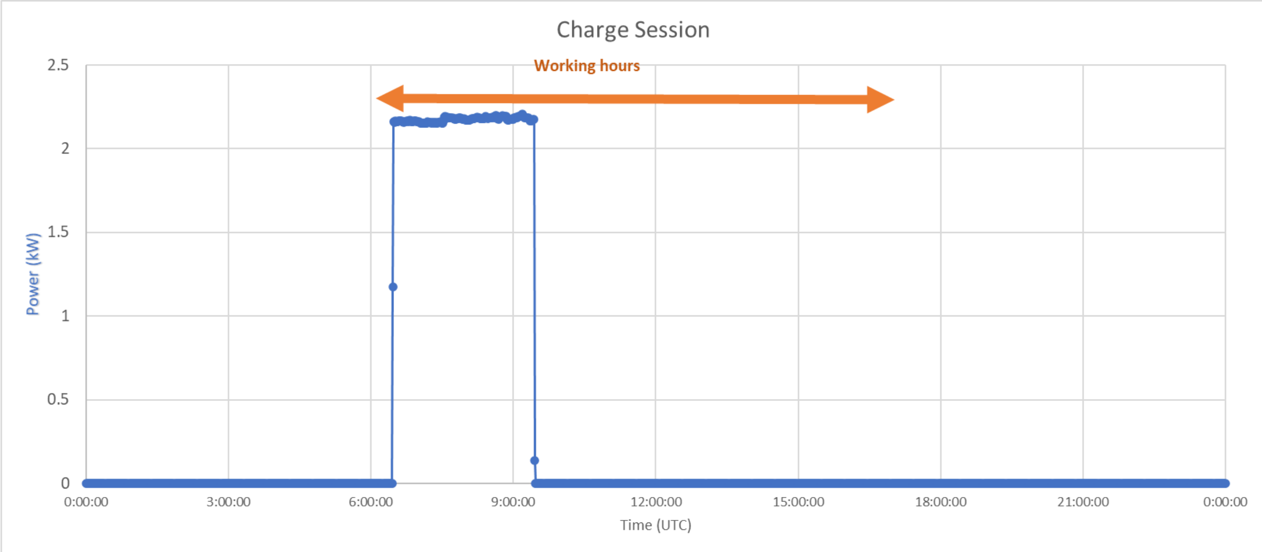

Figure 6-2 Profile for a charge session in BCN.D2

6.2 Overall energy use

The overall energy consumption in BCN.D1 and BCN.D3 corresponds solely to the energy use for charging the batteries of the EVs. By contrast, for BCN.D2 corresponds to the whole office building where the charging points are located. This case is the one that will be presented for analysis here.

The energy consumption varies between summer and winter. There is consumption of HVAC all year round because it is used for ventilation and also for heating of some areas, but in winter the main energy source for heating is gas. A set of figures comparing the total electrical power for the building, the electrical power due to HVAC, and the electrical power due to other appliances, including lighting, is presented in this section. It is interesting to see that in winter, see as example January 2021 consumption in Figure 6-3, most of the electrical consumption is due to other appliances rather than HVAC, notice that the curves in green (total) and blue (other appliances) are very similar. Yet cycles along the day are to be seen, corresponding with working hours. Notice that weekends can be differentiated from working days. However, the pattern along the week varies from day to day and from week to week, being the main reason that there are several labs in the building with high energy demanding equipment and usage changes on a daily basis according to presence of employees, that are only allowed to go to the offices certain days a week to reduce the number of people that are simultaneously working in the installation.

In summer, as seen in Figure 6-4, the overall power consumption is approximately 50 kW higher than in summer, caused by HVAC (yellow curve). Notice also that HVAC consumption varies; this variation is caused by outdoor temperature.

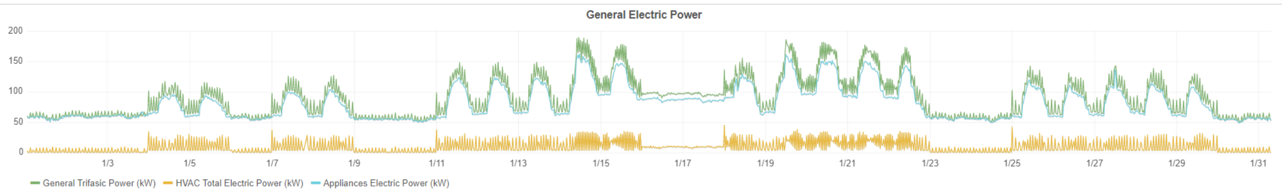

Figure 6-3 Electrical power consumption for the building of BCN.D2 in January 2021

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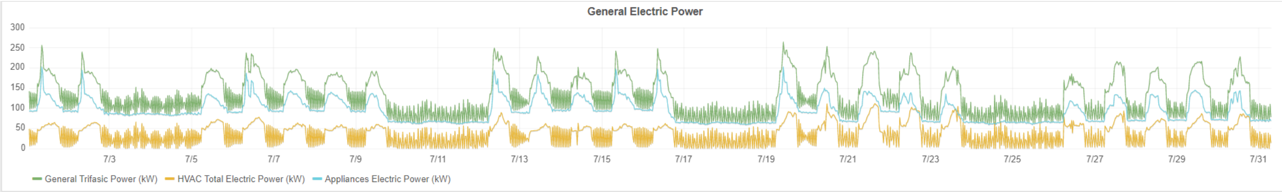

Figure 6-4 Electrical power consumption for the building in BCN.D2 in July 2021

The power consumption of the building always exceeds 50 kW, even in the week of August where the building is closed, as seen in Figure 6-5. That means that the energy used for charging EVs has very low impact in the total energy consumption; however, it is useful to analyse how the charging facilities can scale up.

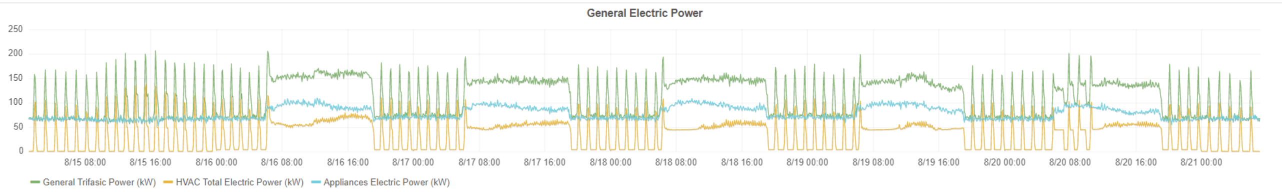

Figure 6-5 Electrical power consumption for the building in BCN.D2 in a vacation week

6.3 Production of green energy

The figures of green energy production presented in this chapter come from the solar plant installed in BCN.D2 demonstrator. The PV panels in BCN.D3 had to be temporary disconnected for safety reasons, since the only consumers are the e-bike batteries and they are not in operation, but since they are in the same region, it can be assumed that the production is similar but scaled down.

Production of green energy varies according to season, as expected. As can be seen in Figure 6-6, the months with higher production are from May to August, included.

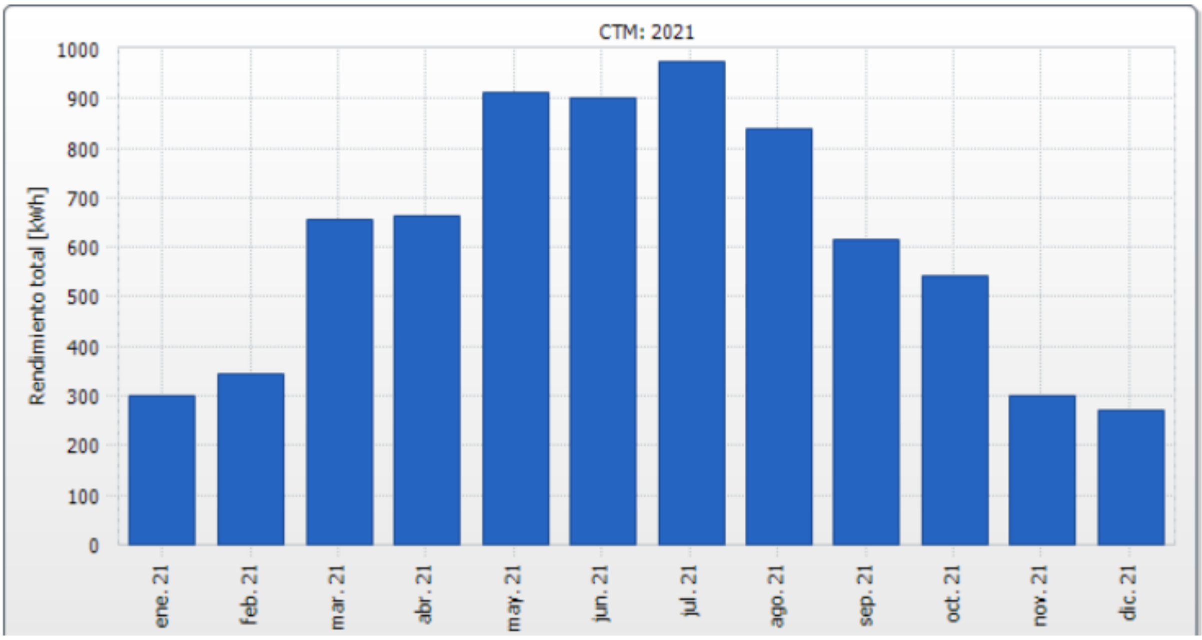

Figure 6-6Monthly solar energy production for BCN.D2

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.

However, in terms of management of green energy, the variability of the production of green energy is a challenge. The daily energy production varies very much between seasons, as shown in Figure 6-7, for the daily production in July and November, 2021. Besides, the shape of the curve changes completely between two days of the same week, as shown in Figure 6-8 for two days in July and two days in December 2021.

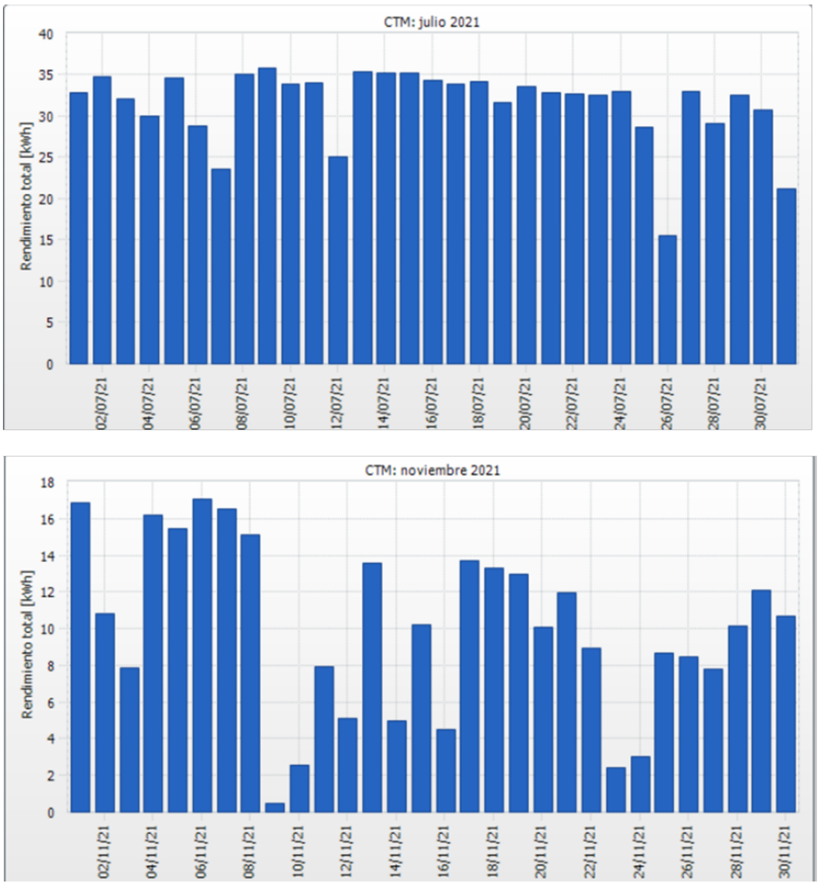

Figure 6-7 Daily solar production for May and November 2021

Taking into account the total energy consumption of the building presented in section 6.2, all solar energy produced is consumed by the building at any time. The power plant can be much extended to supply EVs and other loads of the building.

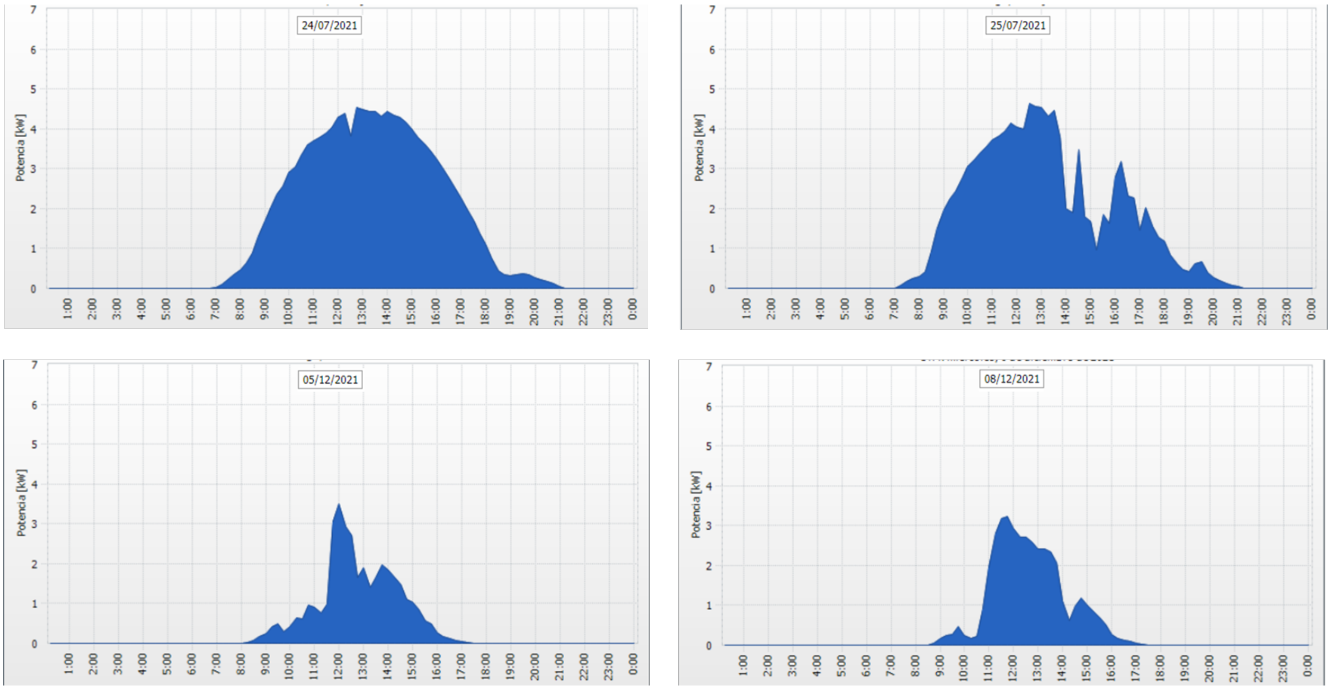

Figure 6-8 PV power for consecutive days in summer and winter

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7 Smart Management System

Smart Energy Management for Barcelona pilots demonstrators focuses on the charging process of the vehicles. It will differ from the as-usual operation "start charging when the vehicle plugs in" to enable:

- The maximization of the usage of energy locally produced
- The minimization of energy cost due to variable energy prices
- The reduction of carbon footprint by taking into account carbon intensity of energy coming from the public grid

The components in place that are involved in the smart energy management are:

- Booking (only in BCN.D2): it provides an estimation of future energy needs to be used in charge sessions, since at the moment of booking the user has to provide the estimated SoC at the moment of arrival. To simplify the booking process, the SoC requested at departure is assumed to be at least 80%. The service was not in operation until the final phase of the piloting activities. On the one hand because it has not fully ready and we wanted to avoid a bad user experience that prevented users to use the charging points, and, on the other hand, because we wanted to collect also base line data for the "as-usual" operation.
- Charging: The energy flow in the charging point depends on the plan calculated by the optimizer. The charging process will not start immediately after plugging in, but whenever the optimizer calculates is best. For BCN.D1 it was agreed that the charging will be "as-usual" and the optimal charging profile will be obtained by the simulator. For BCN.D2, the optimization could be done only after bookings were in place; for the rest of the period, optimal plan can be calculated with the optimizer. For BCN.D3, there has not been tested yet since the demo is on halt at the moment of writing this report.
- Energy Management: The optimal energy plan comes from the criteria above mentioned. For BCN.D1 it is only possible to experiment for simulation scenarios, and, due to late delivery, data from real charge sessions are still to be processed and analysed. For BCN.D2, the goal is to charge the cars with energy coming from the PV plant, on-site, that means that the charging is shifted around 1 hour before it starts charging. In any case, the energy production is used in the building since the production is much lower than the energy consumed. The minimization of the energy cost is more interesting since the hourly price of energy varies on a daily base and the cost of the power connection has 6 different time periods; typically a valley in prices can be found in the early afternoon, soon enough to get the battery charge before EV departure. Similarly, the carbon intensity also varies depending on weather conditions (wind, sun) and bids from producers in the whole energy market, but typically, on sunny days, the optimization under this criterion gives similar results to the maximization of energy locally produced. Finally, for BCN.D3, the main goal is to use the energy locally produced; the capacity of the stationary battery should allow to cover energy needs at night; however, it has not been tested since the driving patterns are still unknown. After a period of collecting historical records for trips, the forecasting algorithm will be able to estimate the energy needs for the next days and other strategies that fully charge the batteries every night will be possible.

As a result of the beta-testing phase and conversations with the users and partners of the rest of pilots, changes have been introduced in the booking app to make the reservation easier and minimize the information to be introduced by the user; thus, only the estimated SoC at arrival is requested among a list of 4 possible status (<25%, <50%, <75%, >75%).

At this point, it is important to record more data related to user behaviour that affects charge sessions (how often they charge, what the SoC is at arrival, how accurate is the estimated time of arrival and departure, …).

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8 Initial lessons learned and technical system (summary)

This section will present a set of lessons learned from the process of putting (or trying) the demonstrators in running mode and collecting as much data as possible. The final lessons learned will be presented in D2.21 Final report for Barcelona pilot -Lessons Learned. This report was expected to be issue in a more intermediate stage to allow improvements and a second round of trials, but it has been postponed in order to have enough data to extract some conclusions.

What we have learned:

- Integration of systems is still a challenging task from a technical perspective, despite the existence of standard protocols. For instance, the OCPI protocol envisions to exchange SoC between the vehicle and the charging point, but most EV manufacturers (or at least the ones we have seen) provide this information. Similarly, using CAN or MODBUS does not avoid several iterations between the extraction of data is successful (issues with misinterpretation, *sui generis* coding or under-documented software libraries). It was clearly underestimated when the scope of the project was defined, and it has been experienced not only in Barcelona pilot but also in Oslo and Bremen.
- Communication between stakeholders has proven to be as challenging as communication between systems. The roadmaps of stakeholders (private companies, public authorities, users) and the project roadmap does not necessarily converge. It is especially difficult to address when the stakeholders are not members of the consortium since there is no legal bound to force to converge. A formal agreement is a good practice, but it has been proven insufficient; it should state clearly the consequences of not fulfilling the commitment and have the means to execute them. Yet, above organisations, the personal communication is crucial: a change in the interlocutor can change completely the course of the project.
- EV driving community is still to small in Barcelona and surrounding area to get a critical mass to test GreenCharge solution. Although the number of EV sales is increasing every year, less than 1% of EV employees drive an EV (bearing in mind that Eurecat is a technology centre and employees are more likely to be early adopters). This makes difficult to get candidates to test and get statistically representative results. Beyond the project lifetime, it jeopardizes the transferability of exploitable results to the private sector until more clear business perspectives arise.
- Continuous supervision is needed: if a system has been successful tested once, twice or more, does not necessarily mean that it will successfully run forever. On the contrary, as soon as it is not in the spotlight (meaning nobody is checking) it stops running for a variety of reasons (changes in format of third parties, ICT related issues, physical damage, …). We have learned to add notifications (using MS Teams) in addition to logs.
- Applications and services need to be very user-friendly: efforts have to be put in delivering the message in the same language as the user. Any effort demanded to the user needs to be expressed in terms of what it the gain or motivation for it. Beta testers may keep trying the application when it fails, but real users will not: testing is very important, especially apps and applications with graphical user interface.

What we have changed:

- Deploy solutions in docker containers limiting the resources used by each process
- Include more validation functions, logs and notifications to detect failures sooner
- Focus on data that is essential to produce simulation scenarios
- Include solutions to protect assets (digital access to e-bike station)
- Simplify the booking app

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9 Further work

To avoid repeating the conclusions extracted from the piloting phase executed so far (those have been already presented in section 8), this section will focus on the work pending until the finalisation of the piloting phase and the project.

The foreseen tasks are:

- Extend the automatic data collection until the end of the project (BCN.D1 and BCN.D2)
- Generate samples of real data that can be used in simulation for the demonstrator with no real users
- Perform evaluation focus groups for implementation and operation of the pilots among the partners involved as part as stakeholders' acceptance input
- Compile as results all the experience gathered during the project including both success and failures. They are equally relevant for replication and extension of the results.

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