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

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GreenCharge Project Deliverable: D2.21

Final Report for Barcelona pilot: Lessons Learned and Guidelines

Authors: Regina Enrich Sard (EUT), Lluis Freixas (ATLAN)

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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

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

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

Executive Summary

This document presents experiences of the measures put into place in the Barcelona pilot in order to be used as lessons learned and guidelines for replicability or extension of the current demonstrators.

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. All together they include components to build measures to improve EV fleet, charging process, smart energy management and business aspects. 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.

The assessment of the pilot will be done through a set of Key Performance Indicators (KPIs) previously defined. During the project, data to calculate these KPIs have been collected, processed and converted into the defined GreenCharge Open Research Data Format for further use in the KPI calculator and the simulator, and to be made publicly available for further research by the end of the project.

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.

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 amount of data collected is smaller than the initially ambitioned, but for all cases it has been possible to take at least some representative samples.

The pilot has experienced big delays that have shorten the monitoring period. 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 shows potential for a smarter energy management in the demonstrators. The low usage of the charging points and the EVs will change in the near future as work in office is reestablished.

The main lessons learned that should be taking into account for replicability are to define the measures involving a multidisciplinary team to have a holistic view, to build a common language among team members and users, to plan and design for interoperability among systems, to use data as the main driver for the definition of the measures and evaluation, and to include supplier's technical support quality and supply chain in the decision-making process for acquisition of devices and services. As part of the project management, documentation is very important for handling take-overs and revisiting taken decisions, and flexibility to adapt to changes in the environment that are unavoidable is a must.

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Table of Contents

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Table of Figures

List of Tables

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

List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
BCN.D1	Barcelona Pilot Demonstrator 1
BCN.D2	Barcelona Pilot Demonstrator 2
BCN.D3	Barcelona Pilot Demonstrator 3
EV	Electric Vehicle
MaaS	Mobility as a Service
CPO	Charging Point Operator
DSO	Distribution System Operator – responsible for operating and maintaining the electricity distribution grid.
RES	Renewable Energy Source (see "List of Definitions" below for detail).
PV	Photovoltaic
CP	Charge Point
SUMP	Sustainable Urban Mobility Plan
ICT	Information and Communication Technologies
LEV	Light Electric Vehicle are electric vehicles with 2 or 4 wheels powered by a battery, fuel cell, or hybrid-powered, and generally weighing less than 100 kilograms.
EMP	Electromobility Provider
B2B	Business to Business
B2C	Business to Consumer
NEMS	Neighbourhood Energy Management System
SoC	State of Charge (see "List of Definitions" below for detail).
DR	Demand Response
GPS	Global Positioning System
CMS	Charge Management System
IoT	Internet of Things
TSO	Transmission System Operator
API	Application Programming Interface
LAN	Local Area Network
ROI	Return on Investment
V2G	Vehicle to Grid, means to use the energy stored in the batteries of EVs connected for charging to provide energy to the grid in peak load situations.

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Abbreviation	Explanation
PHEV	Plug-in Hybrid Electric Vehicle
HVAC	Heating, Ventilation and Air Conditioning
UV	Ultra Violet Radiation
NFC	Near Field Communication
QR	Quick Response code
KPI	Key Performance Indicator
BEMS	Building Energy Management System

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List of Definitions

Table 2: List of definitions

Definition	Explanation
CAN bus	The CAN bus (Controller Area Network bus) is a communication standard for vehicles. It allows microcontrollers and devices inside or outside vehicle to communicate with each other
MODBUS	The MODBUS Protocol is a messaging structure used to establish client-server communication between intelligent devices
OCPI	Open Charge Point Interface is an open protocol used for connections between charge station operators and service providers
RES	Renewable Energy Source is a category of energy sources which does not involve the burning of fossil fuels as part of the energy production process. The most popular RES are photovoltaic panels, windmills and hydroelectric power plants. Typically, the carbon footprint of RES (caused by the building, operation and maintenance of the production facilities) lies in the area of 10 – 50 g CO2 equivalents per kWh, while for fossil energy sources like natural gas, oil and coal the carbon footprint lies in the area of 500 – 800 g CO2 equivalents per kWh. Nuclear power is not commonly counted as a RES, since the energy production process does consume a fuel and does produce a problematic waste (radioactive material). However, its carbon footprint is in the lower end of the RES range.
SoC	The state of charge (SoC) is an indication of the amount of energy stored in a battery. It is given as a percentage, meaning the percentage of the full capacity currently available in the battery. The SoC is difficult to measure accurately, but several methods are available to give an approximate value, and most EVs has an instrument on the dashboard showing the SoC.

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1 About this Deliverable

1.1 Why would I want to read this deliverable?

This document describes the lessons learnt from the implementation the Barcelona pilot in the GreenCharge project. The Barcelona pilot considers situations typically found in large and medium-size cities: Company sites located in the outer regions of the cities, where many employees are commuting from surrounding regions, as well as alternative or complementary options when public transportation is not available or convenient.

Therefore, this document contains lessons learnt from (A) giving commuting employees the chance to recharge their EVs using renewable energy on their employer's site, and (B) having an MaaS option for commuters and self-employed/small businesses.

1.2 Intended readership/users

Expected readers of the Final report for pilots are primarily those who plan to replicate or develop solutions further, take advantage of GreenCharge technologies or can utilise the results:

- Employers considering implementing charging at work options
- Last mile green mobility service providers
- Electromobility fleet managers
- Transport operators considering offering multimodal transport
- Cities and public authorities
- Software developers for energy smart management
- CPOs
- DSOs, aggregators and energy retailers

1.3 Structure

Although part of the information included in this report is also included in other deliverables, it has been considered to add it succinctly for the sake of readability.

The document starts in chapter 2 by presenting the objectives of GreenCharge: how they apply to Barcelona pilot, what have been achieved, the results and the deviations from the original plan.

Chapter 3 describes the operation of the three demonstrators, by recalling the purpose and the components that are part of the solution deployed, as well as providing insights on the experiences gather during the operation.

Chapter 4 summarises the measures implemented grouped by EV fleet, charging, smart energy management and business aspects, as well as the associated KPIs that will be assessed and presented in deliverables of WP5 and WP6.

Data collection has been a key aspect of the project, the mechanisms, results and challenges are presented in Chapter 5.

Chapters 6 and 7 compile the lessons learned from the project and some guidelines and recommendations to help to replicate the demonstrators and, if possible, avoid some problems.

Finally, we present the conclusions and plans after the project.

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1.4 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.

- D2.17 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.
- D2.19 Full-Scale Pilot Implementation for Smart Charge and EV Fleet Management – Description of the Integrated smart charging solution installed, prepared for integrating battery swapping hub and shared homeowner charging points solutions with smart planning, booking and billing solutions and balanced with local energy use and electricity production
- D2.20 Technical Monitoring Report and Feedbacks (Barcelona) - Technical report describing monitored energy loads (EV charging, energy use and production) and results of the smart management, and feedbacks for further development and refinement of business models and technology prototyping
- D2.8 Final Report for Oslo pilot. Lessons Learned and Guidelines – sister deliverable for the experiences gathered in the Oslo pilot
- D2.15 Final Report for Bremen pilot. Lessons Learned and Guidelines – sister deliverable for the experiences gathered in the Bremen pilot
- D5.5-D6.4 Final Result for Innovation Effects Evaluation / Stakeholder Acceptance Evaluation and Recommendation- For D5.5: Describe evaluation results and lessons learned from first iteration evaluation of the integrated technical solution and business models effects, both from field trials of the three pilots and from simulations. For D6.4: Describe evaluation results and lessons learned from further refinement of business model designs and technology prototyping
- 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)

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2 Objectives

2.1 How were the objectives achieved?

The GreenCharge Objectives, as they were stated in DoA are listed below. This section will describe how they were achieved within the three demonstrators of the Barcelona pilot.

Table 3: Objectives addressed by Barcelona pilot

Objective	How the objectives were addressed		
	BCN.D1	BCN.D2	BCN.D3
(O1) Prototype and test business models to support viable business cases for EV charging for urban and sub-urban areas with renewable energy in various contexts	Analysis of green charge branding, charging flexibility and users incentives	Analysis of demand flexibility to take advantage of off-peak hours and future participation in DR programs	Analysis of the improved e-bike sharing service with local renewable energy: operation costs and willingness to pay
(O2) Demonstrate booking services for charging providing EV users predictable access to charging services	Analysis of pattern usage of e-scooter and extracting energy needs	A web-app for charging points reservation implemented: timeslot and energy demand provided by the user in advance and used for smart energy management	
(O3) Demonstrate services for optimised utilisation of existing grid capacities and local RES by implementing coordinated load shifting in neighbourhoods and private ground leveraging available local storage	Simulation of the effect of PV panels to supply energy demand from the battery hub	Combined charging requested by user via frontend web-APP, energy demand from the building and local energy production to reduce energy imported from the grid at peak hours and avoid increasing the power peak by the installation of the charging points	Based on historical records, estimation of energy demand for charging and local production to optimise PV production, battery storage and energy demand from CPs, minimising import of energy from the public grid
(O4) Demonstrate services for management of storage of energy to remedy EV charging in situations with high peak load			Charging of commuters' e-bikes is managed by s/w backend in a way to maximize the use of renewable energy locally produced storing it when the e-bikes are not in the station

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Objective	How the objectives were addressed		
	BCN.D1	BCN.D2	BCN.D3
(O5) Recommend solutions and provide guidelines as a planning tool for successful deployment of EV charging infrastructures. The guidelines will be tailored to use in SUMP processes	Recommendations and lessons learnt from the pilot were given to WP7 and WP8	Recommendations and lessons learnt from the pilot were given to WP7 and WP8	Recommendations and lessons learnt from the pilot were given to WP7 and WP8

The main goals of the pilot as a whole were to evaluate the following objectives:

- Assess how smart energy management reduce the need of costly upgrading of electrical installations and the grid, thus enabling the provision of charging service in a scenario of low but increasing EV penetration.
- Assess how Smart energy management together with EVs offer a business opportunity to exploit energy flexibility in the form of variable tariff schemes or future participation in demand response programmes.
- Assess how EVs foster the penetration of local RES for a win-win situation and how the volatility of PV panels (being the most suitable RES technology in urban environments) can be overcome by the storage capacity provided by the EV batteries.
- Assess how ICT tools can help in user satisfaction and scalability of a service (i.e.: digitisation of e-bike sharing service)
- Evaluate how EV fleets can improve performance (minimization of recharging downtimes) by introducing smart charging management in battery hubs
- Analyse how new business models related to smart billing solutions (incentives, rewards) improve stakeholder acceptance while reducing operation and maintenance costs
- Assess how EV sharing services help to reduce users' (individuals or companies) reluctance to use and buy EVs for urban areas
- Investigate how different charging profiles affect battery health

The following sub-sections will go into the details of how the objectives have been covered in each demonstrator.

2.1.1 BCN.D1: MOTIT - e-scooter with battery swapping

This demonstrator addresses the concerns from a LEV sharing service operator to keep the business viable by reducing operation and maintenance costs while keeping user satisfaction level high. The reduction of costs is achieved by:

- managing energy demand from the charging processes in the battery hub taking into account the fleet energy needs (when the batteries will be needed by the next trip)
- taking into account electricity prices and peak demand
- incentivizing users to adopt a more sustainable driving (less use of energy per km and less worn out of the battery)

To keep the investment low, the existence of PV panels for the production on green energy is only simulated, in order to take an informed decision in the future. However, a change of contract towards the purchase of certified green energy has been adopted to include green branding.

The battery hub is the key element in the demonstrator, and sensors have been added to achieve monitoring of the charging processes and complement the information from the battery usage during the trip. The latter data is useful to calculate energy needs as well as to derive users driving profiles.

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2.1.2 BCN.D2: Charge@work with smart energy management

This demonstrator addresses the issues that might arise in a facility by the introduction of charging infrastructure. The introduction of a booking service enables the sharing of CPs and avoid the need to install an individual CP for each EV, that might be underused. At the same time, it helps to forecast the energy needs by asking the drivers in advance the amount of energy required and the parking time.

From the point of view of the facility manager, it was meant to demonstrate that the charging point infrastructure does not require an increase of the power peak limit (by contract) and the extra demand from the EVs can be handled by shifting charging sessions according to energy needs from the rest of the loads of the building and local PV production.

Although there was no money exchange during the process (the charge was offered for free to employees) willingness to pay has been explored and the legal framework allows the employer to charge for the electricity provided.

An important aspect also demonstrated in the demo is integration of services and tools from different providers, that has been demonstrated through the integration of ZET app for booking through the interaction between an EMP (ZET) and a CPO (EURECAT) through the eRoaming platform provided by HUBJECT.

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

The focus of this demonstrator is set on the integration of ICTs to increase monitoring and control of a fleet of e-bikes of a sharing service and its integration with the public grid. The goal is to achieve a self-sufficient bike station and power the bikes with the renewable energy locally produced. To overcome the existing gap between the time the energy is produced and the time when the energy is needed for charging, a stationary battery has been included.

There is no booking of the e-bikes, thus the energy needs are estimated based on user mobility patterns. Since the service is addressed to commuters working in the area, the patterns should be very regular.

Sensors in the e-bikes enable to track the bikes and increase security (location of e-bikes) and control over the usage of the service.

The demo has served also as a validation for integration of components from different technology providers.

Although there was not money exchange, willingness to pay by users have been analyzed and operation and maintenance costs have been monitored to study sustainability future and scalability of the service.

2.2 Deviations from the objectives during the project phase

The objectives of the pilot have remained the same; however, the number of users and the data gathered have been less than expected, being the main reason the lock-down derived from the COVID-19 pandemic, together with the still low share of electric cars among the targeted users (Eurecat employees).

During the project, MOTIT business orientation changed affecting BCN.D1; the new e-scooter sharing service targets B2B (mainly delivery companies) and is station-based instead of free-floating. The stations are kiosks where the battery hubs are located. The e-scooter has changed as well.

For BCN.D2, the booking service was meant to be used by employees driving from their usual working place to other Eurecat premises. However, due to the low number of users it has been opened also for charging of employees at their usual working place. Besides, no situation where priorization of bookings or reduction of the parking time has arisen.

For BCN.D3 some vandalisms issues arose during the disruption of the service due to COVID-19 mobility restriction and some modifications in the control access are being developed, not initially planned.

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2.3 Results based on the DoA

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

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

Following, the results achieved in each demo regarding the above-mentioned topics are presented.

2.3.1 Evaluation results and lessons learned (R_ELL)

The DoA (section 1.3.1) defines seven innovation scenarios. How these scenarios have been demonstrated in Barcelona pilot and the results obtained are presented in the following table.

- Scenario 1: Charge planning and booking
- Scenario 2: Charging at booked Charging station
- Scenario 4: Home charging in older (groups of) residential or working buildings with common internal grid and parking facilities, or at work in (groups of) buildings with similar limitations

Table 4: Innovation scenarios mapped to results for Barcelona pilot

Innovation scenario	Results from BCN.D1	Results from BCN.D2	Results from BCN.D3	Contribution to objectives
1. Charge planning and booking	• Energy needs extracted from pattern usage of e-scooters	• App enables booking of charge point and getting energy needs and arrival and departure time • Information to be used by NEMS		(O2) *booking system* (O4) *integrated smart charging solution* (O5) *user interface*
2. Charging at booked Charging station		• App enables start/stop of charging at booked charge point • Charging system to monitor and control charging process; detect deviations according to plan (booking) • Interaction between EMP and CPO through roaming platform		(O2) *booking system* (O4) *integrated smart charging solution* (O5) *user interface*

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Innovation scenario	**Results from BCN.D1**	**Results from BCN.D2**	**Results from BCN.D3**	**Contribution to objectives**
3. Booking enforcement		• Channel to communicate a car parked with no active reservation; not tested because such situation did not happen. • A reputation system to grant higher priority to users that fulfil booking request was designed. However, it was no chance to put it in place.		(O2) *booking system*
4. Home charging in older (groups of) residential buildings with common internal grid and parking facilities	• Battery hubs for charging swappable batteries • Monitor SoC in the battery hub and the e-scooter	• 3 charge points installed in 2 buildings • NEMS supports load shifting and reduces grid load • Integration of solar energy in NEMS	• 5 charge points installed in bike station • PV panel and stationary battery for station self-consumption • Back-end system to control charging process	(O3) *cost-efficient building-charging* (O4) *integrated smart charging solution*
6.Reacting to DR request		• NEMS takes into account dynamic power constraints; no actual handling of DR requests from third parties		(O3) *cost-efficient building-charging*

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Innovation scenario	Results from BCN.D1	Results from BCN.D2	Results from BCN.D3	Contribution to objectives
7. E-Mobility in innovative 'mobility as a service'(MaaS)	• e-scooter App shows trip records • e-scooter back-end gets user profiles • e-scooter back-end gets energy needs		• ebike App enables control access of station and bikes • ebike App shows trips records • Sensors to track bikes • Sensors to monitor SoC • Back-end to interact with charging system and NEMS	(O1) Prototype and test business models to support viable business cases for EV charging for urban and sub-urban areas with renewable energy in various contexts;

2.3.2 (R_TP) Technology Prototypes

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

- *D2.18 Pilot Component Preparation for Full-Scale Pilot (Barcelona)* - this deliverable describes the deployment and the testing of software and hardware components to be used in the pilot, to prepare for the full-scale pilot implementation.
- *D2.19 Full-Scale Pilot Implementation for Smart Charge and EV Fleet Management (2)* - this document describes the implementation of the Barcelona pilot.

A summary of the deployed hardware and software is shown here.

Table 5: Summary of hardware and software components in Barcelona pilot

Service	Component name	Description	Demo site	Type
EV In-vehicle system	Atlantis Fleet app	It's the user interface with the e-bike sharing service. It allows to find an e-bike available, track it in real time and read the SoC.	BCN.D3	SW
	Scooter user's mobile app	It's the user interface with the scooter sharing service. It allows to find a scooter available, lock/unlock it, open the trunk, track it in real time and read the SoC.	BCN.D1	SW
	GPS tracker devices	GPS tacker device to get the e-bike/e-scooter location. It has both digital and analogue inputs and also CAN BUS input to collect data.	BCN.D1 BCN.D3	HW

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Service	Component name	Description	Demo site	Type
Charge Service Provisioning	Journey planner app	Help users to drive or ride to their destination.	BCN.D3	SW
	Booking system	Enables Eurecat employees to book a charging point in Eurecat premises.	BCN.D2	SW
Fleet management	Atlantis Fleet platform	It's the interface with service administrator to manage the fleet. It collects data from e-bikes and GPS trackers.	BCN.D3	SW
	Scooter shared services fleet management	It's the interface with service administrator to manage the fleet. It allows service operator to receive information about the e-scooters that need to be charged and plan an optimized battery swapping	BCN.D1	SW
EVSE	Battery swapping in hub	The battery swapping hubs allow to centralize and optimize the battery charging process.	BCN.D1	HW
	Charging point (Eurecat)	Charging point installed in Eurecat premises that will be used by Eurecat employees.	BCN.D2	HW
	Charging point (St. Quirze)	Charging point for e-bikes installed at parking & charging station.	BCN.D3	HW
Charge Station Operation & EV Charging	Charge management system (CMS)	Control the charging process of a charging station.	All	SW
Local energy Management	SEM scheduler	Calculate the optimal schedule of all loads and local RES for the optimization criteria defined and user preferences/needs.	All	SW
	SEM forecaster	Forecast of the energy demand needed to properly plan the assets. The forecasting is done based on historical energy demand information and context variables such as weather forecast and calendar.	All	SW
	PV panels	PV panel to provide green energy locally produced at premises/e-bike site.	BCN.D2 BCN.D3	HW

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Service	Component name	Description	Demo site	Type
	Stationary battery	This battery stores the electric energy generated by the PV panels in order to be used on the charging point.	BCN.D3	HW

2.3.3 (R_BM) Business Models

The business model developed for Barcelona are described in *D3.4 Final business models results*. A summary of them is included in the following sub-sections.

2.3.4 BCN.D1 – MOTIT

Barcelona Demonstrator 1 operates in the shared LEV market and offers a shared e-scooter service. MOTIT is the orchestrators, who pays MOTIT pays for the electricity used for charging the shared LEVs as a variable fee per kWh (differs between day and night). Users of this service benefit from this flexible and sustainable mobility solution. They have to pay a fee per minute for the use of a shared LEV. In case they opt for the eco-driving mode, the users can benefit from a 15-20% discount. MOTIT can reduce energy usage (and corresponding emissions) and save costs on maintenance if many users opt for the eco-driving mode.

Within BCN.D1, the orchestrator bundles the following key elements and assets:

1. E-Scooters (+ IoT): the shared LEVs that are available for end-users
2. Battery hubs: the locations where the swappable batteries are charged.
3. Booking application: required for booking and using a shared LEV
4. Software (back-end): this is the shared services fleet management system

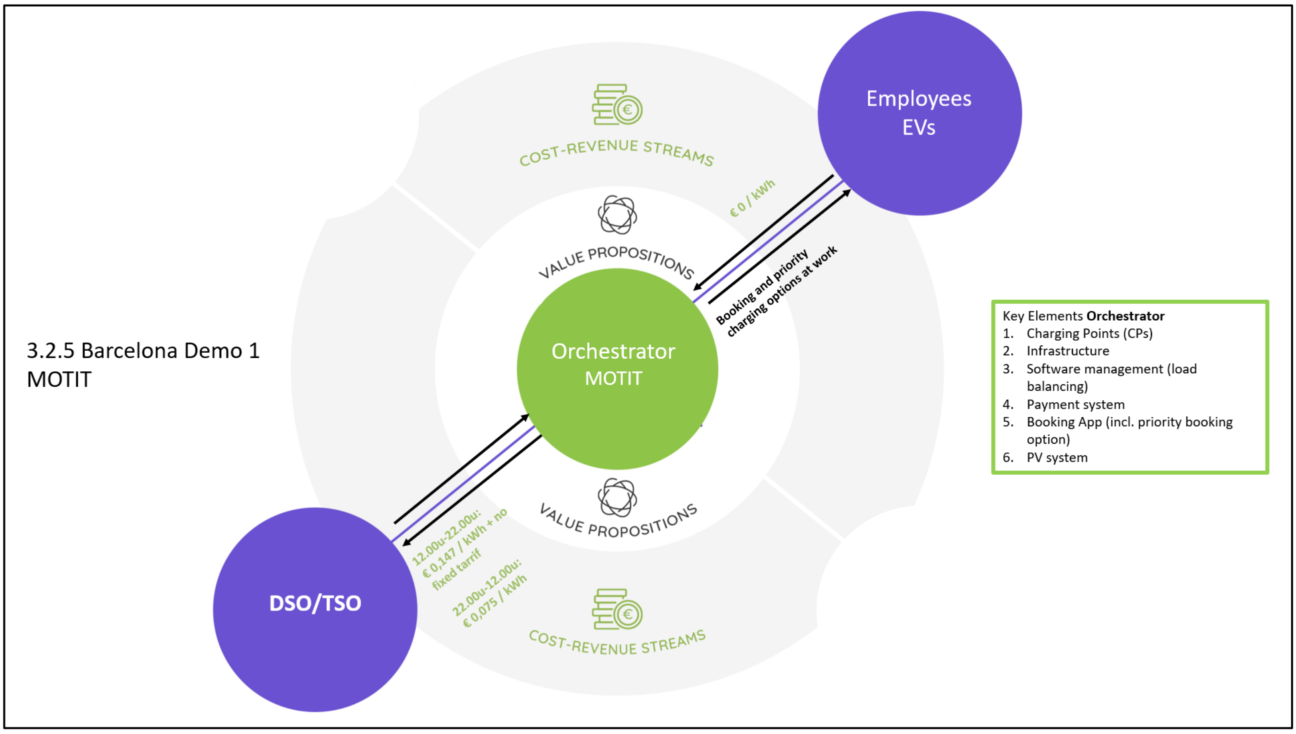

Figure 2-1: GreenCharge Business Model for Barcelona Demonstrator 1 – MOTIT

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.

2.3.5 BCN.D2 – Charging@work with smart energy management

The EURECAT demo operates in the smart charging market for employers with parking spaces and its employees/visitors with EVs.

The orchestrator, Eurecat, pays for energy and grid used to the DSO, TSO and energy retailer. The fee includes a peak power term and an energy term that varies hourly. The customers at Eurecat are its employees and visitors of Eurecat's premises. These users can book their charging point in advance in order to ensure a guaranteed availability. In the current situation, these users do not have to pay a fee for charging their car at Eurecat's premises.

Within BCN.D2, the orchestrator bundles the following key elements and assets:

1. Charging points and grid infrastructure: the charging points and required grid connections at Eurecat premises
2. Energy management system: this software is used for load balancing and ensures that demand and supply of (renewable) energy is well managed
3. Payment system: users pay for their charging session through this payment system[1]
4. Booking app: this application enables EV drivers to book the charging point in advance
5. PV-system: the PV panels produce renewable energy to be used at Eurecat's premises

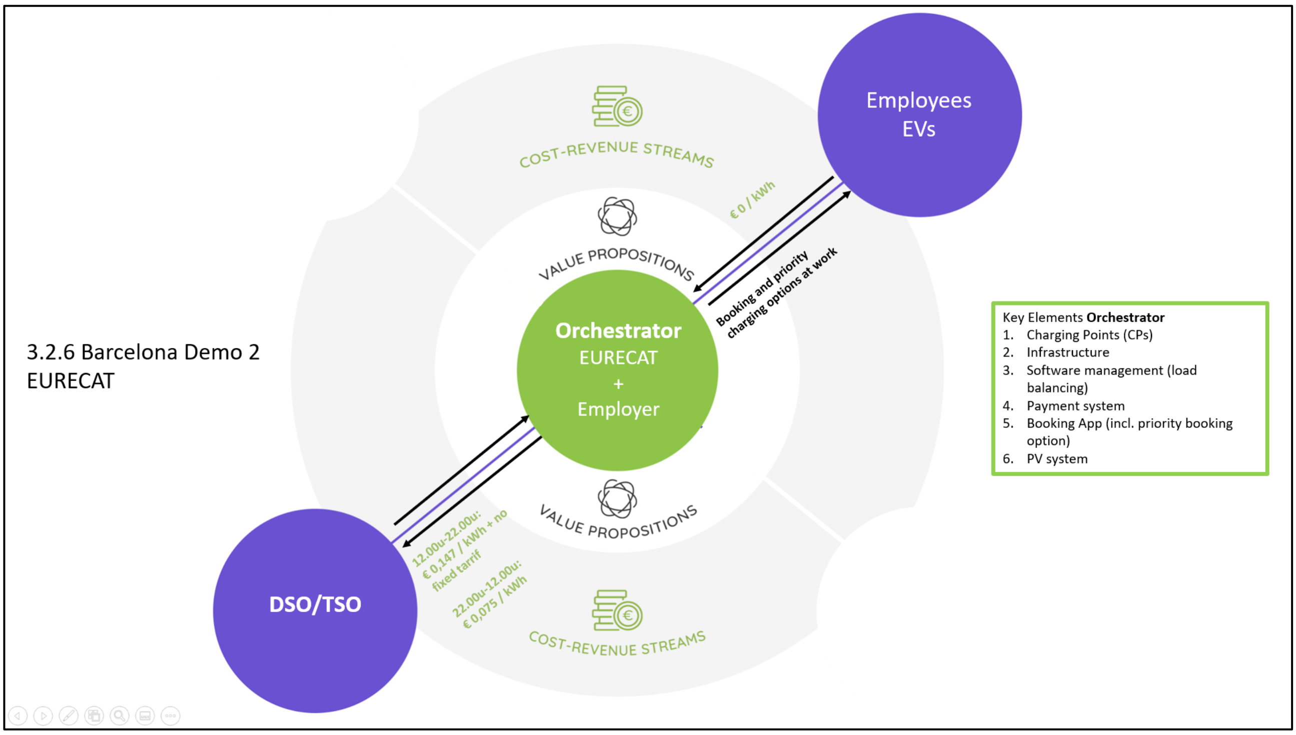

Figure 2-2: GreenCharge Business Model for Barcelona Demonstrator 2 – EURECAT

2.3.6 BCN.D3 – St. Quirze e-bike sharing service

The St. Quirze demo operates in the shared or rental bike market at train stations.

Within BCN.D3, the orchestrator bundles the following key elements and assets:

[1] Currently, no payment system is used at Barcelona Demonstrator 2. However, in the future users will be charged for charging their EV and have to pay through a payment system.

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

1. E-bikes: the shared e-bikes that can be used by commuters for their trip from the station to their company site
2. E-bike storage at train station: the storage where the e-bikes are charged
3. IoT sensors for e-bikes: used for, among others, geo-positioning and reading SoC
4. Battery storage at train station: a surplus in renewable energy produced by the PV panels is stored in the battery storage system
5. PV-system: the PV panels produce renewable energy to be used for charging the e-bikes
6. Atlantis Fleet app: this is the user interface with the e-bike sharing service and can be used for finding an e-bike, read the SoC, get route history and get directions to the charging station

The orchestrator pays for energy not covered by local RES and grid used to the DSO, TSO and energy retailer. The fee includes a peak power term and an energy term that varies hourly. Employees commuting to their work and travelling by train can make use of the shared e-bikes offered by the St. Quirze Town Hall. Employers at the nearby business park can arrange that their employees can make use of these shared e-bikes for a certain period. At the moment, no fee is charged for using the shared e-bikes.

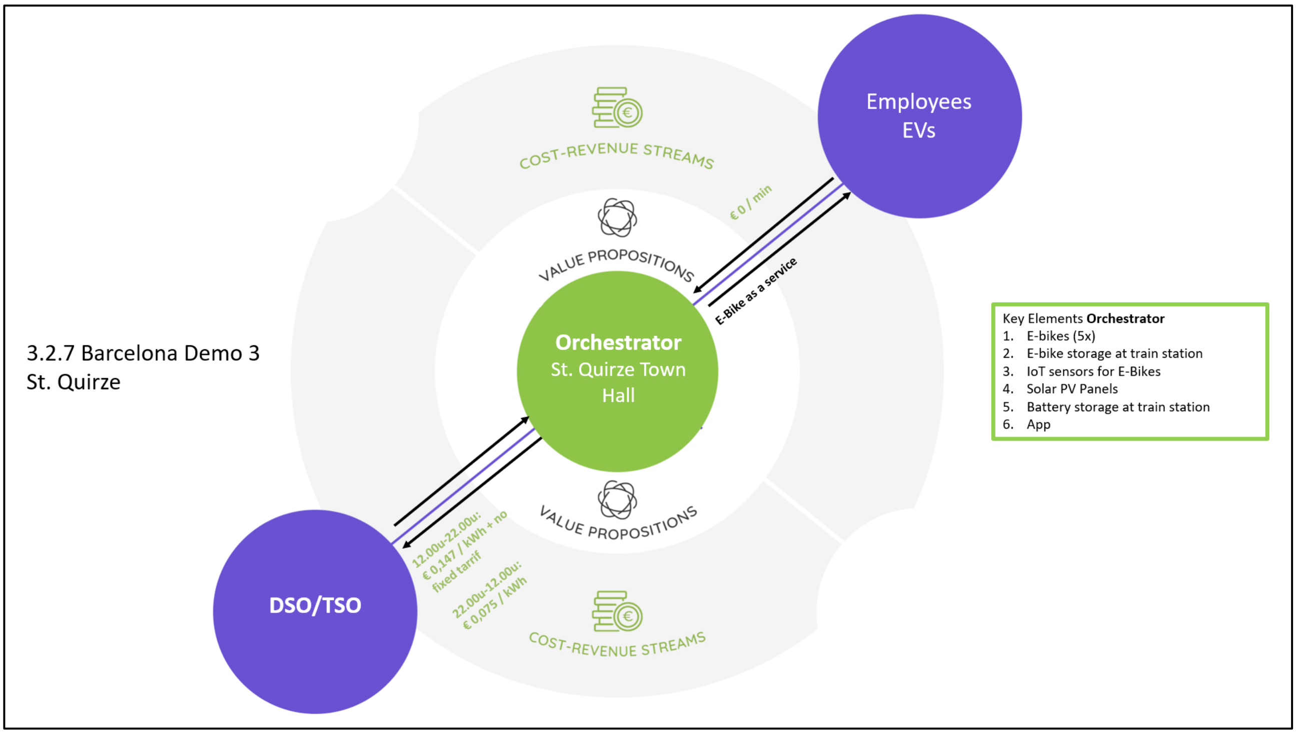

Figure 2-3: GreenCharge Business Model for Barcelona Demonstrator 3 – St. Quirze

3 Operation of the Barcelona pilot

This chapter describes the Barcelona pilot in general, how it was planned, how it was deployed, which hardware and software solutions that were developed especially for GreenCharge, together with standard solutions chosen to make it all work as proposed in DoA (by demonstrator).

3.1 Description of the demonstrators

3.1.1 General description and description of demonstrator sites

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.

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.

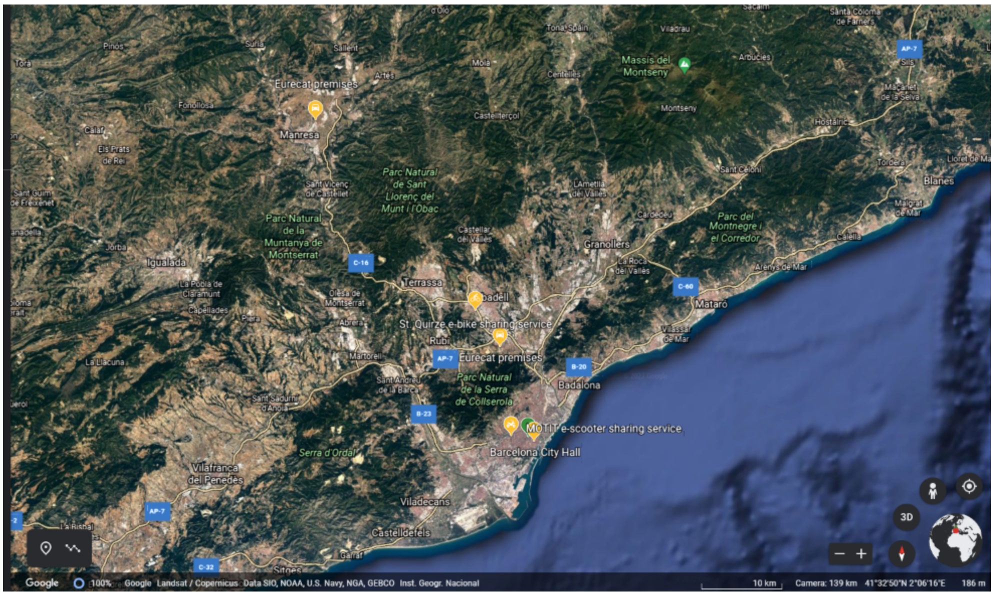

Figure 3-1 Location of Barcelona demos

3.1.2 Description of deployed hardware and software

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

- *D2.18 Pilot Component Preparation for Full-scale Pilot (Barcelona)* - this deliverable describes the deployment and the testing of software and hardware components to be used in the pilot, to prepare for the full-scale pilot implementation.
- *D2.19 Full-Scale Pilot Implementation for Smart Charge and EV Fleet Management*- this document describes the integrated smart charging solution installed, prepared for integrating battery swapping hub and shared homeowner charging points solutions with smart planning, booking and billing solutions and balanced with local energy use and electricity production

A summary of the deployed hardware and software is shown in Table 5.

In this sub-section, an overview of the main components in place and their interactions are included.

<u>BCN.D1 – MOTIT e-scooter sharing service</u>

Sensors located in the e-scooters (in-vehicle system) monitor battery SoC, speed and location, among others. This data is sent to the back-end system (fleet management system) where it will be used to define energy needs and for user profiling.

The scooters on the street can be unlock using the MOTIT app. This app also provides information to the user such as routes and historical records of usage.

The batteries from the scooters are swappable. Fleet operator staff replace depleted batteries with full batteries. Batteries are brought to the battery hub to be charged according to next trips needs and slot availability.

The collected data related to energy usage in the e-scooters and the charging sessions is used for simulations and published as open research data.

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.

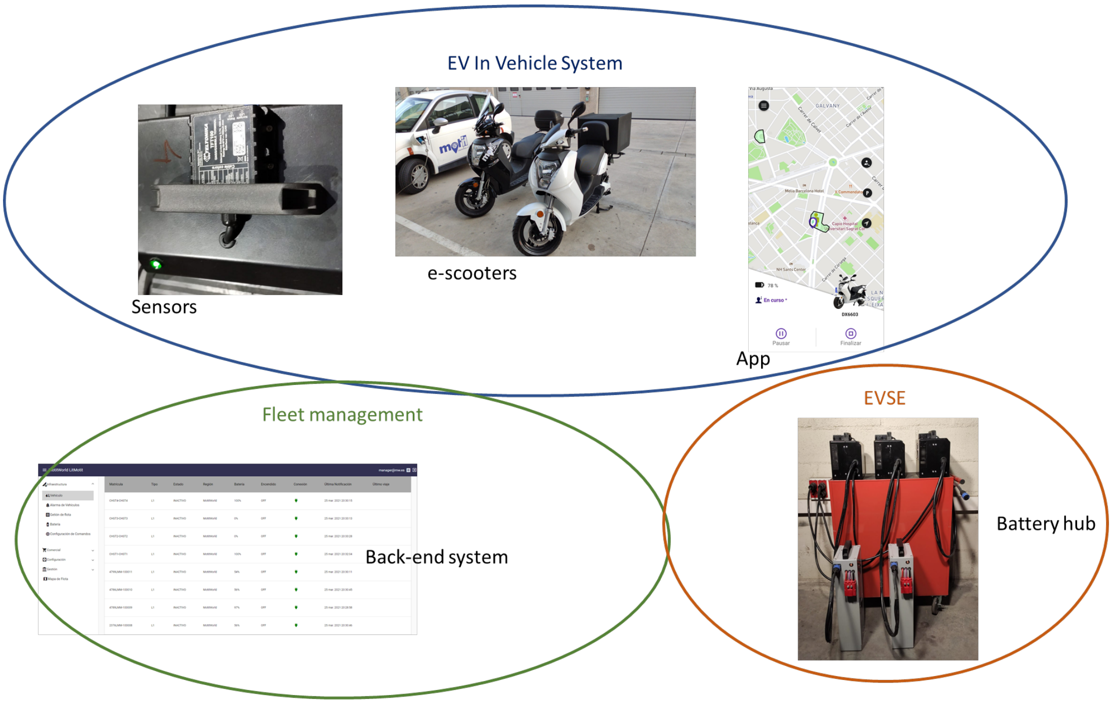

Figure 3-2 Main components of BCN.D1

<u>BCN.D2 – Charging@work with smart energy management</u>

The user books a charging point using the booking app notifying the time slot and the estimated energy required. Apart from the EUT booking app, the ZET app has also been tested to show interoperability through Hubject roaming platform.

Information about bookings and control of arrivals and departures are managed by the charging system, which interacts with the NEMS. The NEMS receives data from the charging system, the building (through the BEMS), the PV panels through the inverter and from third party providers (prices from eSios, energy mix from REE-Entsoe and weather conditions from Darksky).

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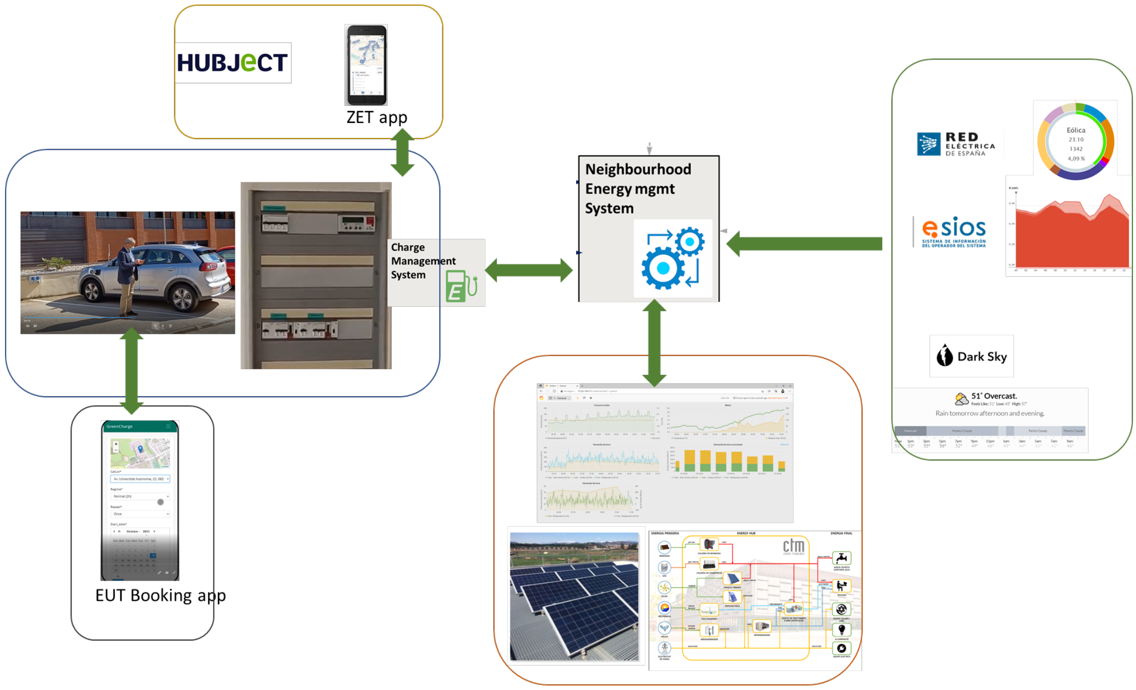

Figure 3-3 Main components of BCN.D2

<u>BCN.D3 – St. Quirze e-bike sharing</u>

Sensors located in the e-bikes (in-vehicle system) monitor battery SoC, speed and location, among others. This data is sent to the back-end system (fleet management system) where it will be used to define energy needs and for user profiling.

The e-bikes are parked at charge station where authorized users can get access and take an e-bike using the Atlantis Fleet app. This app also provides information to the user such as e-bike usage time, battery level, routes and historical trips. The user can navigate to destination through the app and also provide information about incidences during the use of e-bike

The e-bike fleet manager can monitor the service (fleet management system). Information like availability and SoC of e-bikes is given at real time so fleet manager can take decisions upon it.

The NEMS receives data from the charging system, the PV panels through the inverter and from third party providers (prices from eSios, energy mix from REE-Entsoe and weather conditions from Darksky) and decides which of the charge points should be enable and allowing charging at a given time.

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.

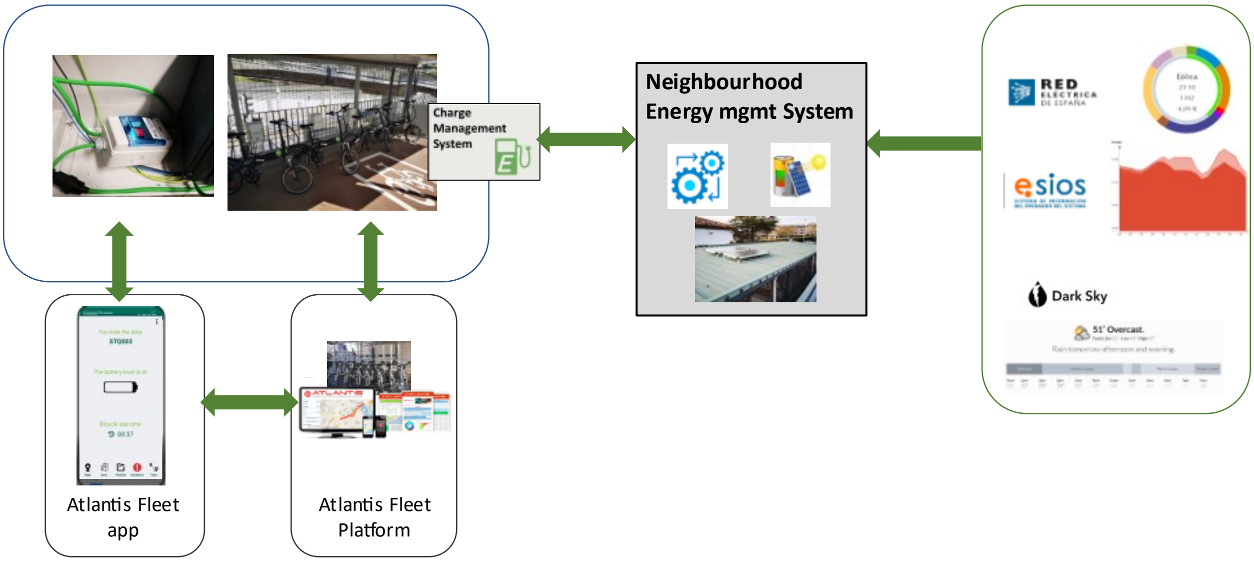

Figure 3-4 Main components of BCN.D3

3.1.3 Systems developed and/or extended from existing background

The Barcelona pilot implementation has been both by both new developments and also extension/updates of already existing components from partners.

The developments done are basically in terms of creating new interfaces with users like done for BCN.D2 and BCN.D3 where apps have been developed for booking or as interface with e-bike sharing service. And also creating or adapting communication interfaces between systems.

The following table summarizes the developments done in the three demonstrators during the project period (*For more information see deliverable: D2.18 Pilot Component Preparation for Full-Scale Pilot (Barcelona)):*

Sub-system role	Component name	Type	New vs extension	After GreenCharge	Demo site	Responsible partner
EV In-vehicle system	Atlantis Fleet app	SW	New development	Android/iOS native app for user interface with sharing service	BCN.D3	ATLANTIS IT
	Scooter shared services app	SW	Needs adaptation	User interface with battery hub points	BCN.D1	MOTIT
	IoT and GPS tracker devices	HW	Needs adaptation	Devices integrated into Atlantis Fleet platform including CAN integration	BCN.D3	ATLANTIS IT
Fleet management system	Atlantis Fleet platform	SW	Needs adaptation	Devices integrated, access control to charge station, integration APIs	BCN.D3	ATLANTIS IT

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	Scooter shared services fleet management	SW	OK		BCN.D1	MOTIT
Charge management system (CMS)	Algorithm for vehicle autonomy calculation	SW	Needs adaptation	Get historical data, test batteries and refine algorithm	BCN.D2, BCN.D3	EURECAT
	Battery swapping in hub	HW	OK		BCN.D1	MOTIT
	Charging point (Eurecat)	HW	Needs adaptation	Communication interface and energy metering	BCN.D	EURECAT
	Charging point (St. Quirze)	HW	Needs adaptation	Update plug, add communication interface	BCN.D32	MILLOR ENERGY
	Booking system	SW	New development		BCN.D2	EURECAT
	Charge management system	SW	New development		BCN.D2, BCN.D3	EURECAT
Neighbour. energy management system (NEMS)	SEM scheduler	SW	Needs adaptation	Add API	BCN.D2, BCN.D3	EURECAT
	SEM forecaster	SW	Needs adaptation	Customization tasks	BCN.D2, BCN.D3	EURECAT
Local renewable energy source	PV panels	HW	OK		BCN.D2	EURECAT
	PV panels	HW	OK		BCN.D3	MILLOR ENERGY
Local battery storage	Stationary battery	HW	Needs adaptation	Communication interface and energy metering	BCN.D3	MILLOR ENERGY

3.2 Operation of the demonstrators

This subsection will provide insights on the operation of the three Barcelona demonstrators

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

The demonstrated was designed and planned according to the MOTIT service in Barcelona in 2019: a free-floating e-scooter sharing service open to citizens. However, when the lock-down occurred, the service was discontinued due to mobility restrictions. When it was allowed to resume the service, the batteries had gone depleted, and it was impossible to restore them. That fact was due that the energy consumed by the ICT sensors of the e-scooter had drained the battery. The energy is very low, thus the battery management system due not interrupt the supply even if the SoC goes below what it is considered the critical level.

MOTIT went through a re-orientation of the service and created a new business model targeting delivery companies that saw how the workload increased dramatically. The operation was changed also from free-floating to station-based using existing shops and kiosks as station, and involving shop tenants as fleet operators taking care of swapping of batteries and interaction with the users. The model of the e-scooters was also changed, new sensors were installed and they went to a homologation process that took longer of expected, also because most services were affected by COVID-19 and long waiting lists were produced.

Once in operation, as every new created business, it has taken time to get users to know the service and use it, thus the number of usages has been smaller than expected.

Due to the reduction of the running phase, the service has been operated “as usual”, using the gathered data as base line, and defining what-if scenarios in the simulator.

BCN.D2 - Charging@work demo (EURECAT)
The launch of the demonstrator was done in 2 phases: first 2 charging points where open in one of the premises (Cerdanyola), and some months later, the third charging point was open in the second premise (Manresa).

Initially, the service was planned to provide service to employees visiting another premise different from their usual working place, but due to the reduce number of EV drivers, it was open to any employee, either at their usual site or visiting one. Some of the targeted employees (those driving an EV) quit Eurecat between the first survey and the actual operation of the demo.

Due to home office policy coming into force the first week of March 2020 at Eurecat, the operation was suspended for many months. Home office policy has been into place until 14-03-2022. By then, employees are invited to work at least 2 days in the offices. In the meantime, however, depending on the severity of the pandemic, some employees went now and then to the offices. Two of these employees driving an electric car had been using the charging points more or less regularly.

It was planned to use the service without booking for a certain period to get base line data and then introduced the booking app to the users to evaluate user’s acceptance and to see the benefits of knowing the energy demand in advance. The app was only introduced very late and casually used by users. The main feedback was that it was difficult to forecast energy needs in advance, and the common practice is to ‘book’ the charging point for a regular use always introducing the same energy request. It was somehow difficult to explain the need for booking when the capacity of the installation has never been exceeded (only once the 2 charging points were occupied simultaneously).

Booking of charging points often encompasses the need to deal to enforcement to guarantee that the charging point is ready for use for those users that have booked it. In the demonstrator, no situation needing enforcement arose. As mentioned before, the number of users going to the office was very low and the outdoor parking was quite empty most of the time. Only once a truck parked in the spot of the charging points, and it had highest priority, since it was for employees’ yearly health check. Should it be known in advance, we would have been able to reject reservations on advance. Additional procedures have to be established for communication of such events.

The NEMS was only demonstrated partially. It was in place and running, but the flexibility was quite reduced. The local renewable energy produced by the PV panels on site is consumed by building background loads. Optimization according to spot prices was tested to slightly reduce the cost of the charging session. It was not allowed to optimise other loads of the building such and HVAC due to the fact that ventilation and air quality paramount any other criteria, such as efficiency: since March-2020, windows are open most of the time and/or forced ventilation is activated to ensure air renewal.

Apart from the reduced number of users, the most challenging aspect of the operation was to keep the systems producing data on a continuous manner. Many issues arose causing one or several systems stopping: change in protocols, electricity cuts, re-configuration of LAN (sub-networks), expiration of software licences, among others.

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In order to communicate the existence of the charging facility to Eurecat employees, taking into account that employees come and go, two surveys were issued as well as a number of news posted in the internal newsletter.

BCN.D3 – St. Quirze e-bike sharing service

The operation of this demonstrator has been compromised by the disruption caused by COVID-19 plus a chain of side-effects. By the time that the COVID-19 arrived, the partners were preparing a press release to announce the launch of the demonstrators within few week time. However, the pandemic imposed restrictions on mobility and when these restriction were soften, the personnel in the townhall were shifted to new tasks to support citizens in more urgent issues. In between this period, the responsible for the project in the townhall left and no one took over until 16 months later, municipal elections were also held during this period, new roadmaps were designed and no one in the townhall with background or enthusiasm about the original project were left.

Also changes in the personnel in the townhall, Enchufing and Eurecat had caused a certain lost of traceability and an extra effort to put everything to run again (documentation missing, keys lost, …).

Also during the discontinuation of the service, intruders entered the bike station and some vandalism events occurred that caused some damage to equipment installed and the stolen of a bike charger and the inverter. Yet, due to inactivity, the bike batteries equipped with sensors were depleted. It was the same effect observed in BCN.D1; the consumption of the sensors low enough to not be detected by the battery management system, but big enough to take the battery to SoC of 0, which makes it very difficult to restore it back to operation again.

Due to the events, extra efforts were needed to secure the bike station with an electronic lock, to take the bikes to the workshop for maintenance and to replace the damaged batteries.

The running of this demonstrators has been a chain of déjà-vu situations: a push to make it ready for operation and a break, and again a push and a break.

Finally, we manage to use the bikes in beta-testing mode by members of local partners. The data gathered is useful for simulations to verify the impact of the smart energy management to align local production, storage and demand. The trips done were chosen to have a similar length to the real ones.

However, we lack feedback for real users after the GreenCharge measures applied. A survey among users of the service was issued at the designing phase to learn about the preferred functionalities.

Currently, the townhall is working to put into operation a rotary parking spot for personal mobility vehicles (bikes, e-bikes, scooters, e-scooters). The facility is also located in the vicinity of the train station and will have charging infrastructure. This model will serve more citizens with less investment (the vehicles are owned by the user).

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 Measures and KPIs

4.1 Measures implemented in the pilot

4.1.1 BCN.D1 : MOTIT e-scooter sharing service

The measures implemented in this demonstrator are grouped in the following table (see D5.4-D6.3 for more details)

Measure groups	Measures
EV Fleet	• Shared EVs
Charging	• Battery swapping and charging • Flexible charging
Smart energy management	• Local RES • Optimal and coordinated use of energy
Business aspects	• Payment for sharing EVs • Rewarding Eco driving

EV Fleet measures: The measure affected two sharing services owned by MOTIT, the first one is B2C and the second one is B2B. The reason for selecting two of them was due to an internal re-definition of MOTIT business model and the reduce number of usages and vehicles for the B2B new business model. The e-scooters are available for users to be used by minutes or by service within an area. It addresses those users that don't use the e-scooter frequently enough to buy a still expensive EV, or those users or companies that temporary need additional vehicles. For the B2C service an app allows the booking of EV and the key-less access to EV. The fleet management system monitors the EVs through interactions with the in-vehicle systems and uses the information received (SoC, speed, acceleration, driving distance) to manage the fleet.

Charging measures: The measure is based on replacing plug and charge to battery swap. It can be done in e-scooters because the weight of the battery is low enough to be manipulated by a person without the help of additional assistance. Battery swapping enables to reduce stop times for charging nearly to 0; this is seen as a 'must' for urban personal mobility, and it is even more important for professional usage as delivery companies. Tenants (mobility providers) perform battery swap when the e-scooter is not in use, and they take care of the charging of the batteries in the battery hub. The EV user can go to a kiosk to swap battery if they need extra charge. Flexible charging can be done if it is known when the battery will be needed again for another trip. For anew services it is difficult to forecast what will be the future needs, but with the data gathered from operation "as usual" some simulations were planned to show the hesitating operator how flexibility can reduce energy cost.

Smart Energy management: Likewise flexible charging, the introduction of PV panels can help in reducing energy used from the public grid. It is of special interest as the prices of electricity go up and the PV panel cost goes down. However, the measure was only meant for simulation of what-if scenarios since: no investment cost on PV infrastructure was allocated, the operator had a flat tariff and it was not affected by the spot price (until the contract last), and the retailer sells certified green energy from the public grid. The input data for optimization comes from the charging sessions of individual batteries, the hypothetical solar production of a PV panel located close to the battery hub, and the spot price from the whole energy market.

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.

e. A posteriori analysis is done providing the flexibility potential and the ROI if a smart energy management approach is implemented

Business aspects: The payment for the sharing of EVs has been re-defined during the project. Prior, the payment was done for time of use (after each trip the amount was charged to the user's credit card), and had different cost for subscribed user paying a monthly fee from that for occasional users. During the project, for the B2B approach it was decided that the service was paid in advance with a voucher. The user should select the time (30 minutes, 2 hours, 8 hours, etc.) and the period (day, week, etc.). This approach eases the billing, that now it is done in the shops or kiosks. The tenant registers to the platform the voucher that is bought in advance in the same shop. This is the second change in the business model, MOTIT provides the assets, operates the platform and support the fleet operator (remotely), but the shop/kiosk tenant on site operates the fleet and interacts with the end user. Another business aspect is to involve the user to reduce operation costs. It has been observed that for similar journeys, the energy consumed varies very much from user to user; a smoother driving pattern saves energy and extends battery lifespan, both factors are beneficial for the fleet operator. The benefit to the user is in the form of a discount per trip. Taking data from trips, the most suitable candidates have been identified and a survey to get feedback on the willingness to participate and the type/amount of incentive needed have been analysed.

4.1.2 BCN.D2: Charging@work with smart energy management

The measures implemented in this demonstrator are grouped in the following table (see D5.4-D6.3 for more details)

Measure groups	Measures
Charging	• Shared CPs • Roaming • Booked charging • Flexible charging • Priority access to CP
Smart energy management	• Local RES • Optimal and coordinated use of energy • V2G (Simulated)

Charging measures: 3 charging points in 2 different locations have been put at the service of Eurecat employees. Initially no booking through the webapp was mandatory to collect base line data (and also due to limitations to work in the offices. Awareness was raised among EV owners by means of surveys, news in the internal newsletter and by word of mouth. Due to low occupancy, no further management to solve conflicts was required. The flexible charging was applied taking into account spot prices since the local PV production is all use in the building with or without cars charging. The users used to stay in the premises for around 8 hours or more, while the battery needed 2-3 hours to charge (PHEV). During the project duration, users don't pay for the charging, but a record of the charging sessions and the equivalent energy and CO2 impact is calculated and can be seen in the historical records. A priority policy was designed, but it was not needed to put it in place. The policy was meant to choose which bookings were to be accepted or rejected in case limited availability (more cars willing to charge than charging points available). For that, users were assigned a priority (reputation) according to prior charging sessions (Did they arrive on time, or arrive at all? Did they specify an estimation of energy needed? Did they leave when expected?). Unfortunately, currently, the number of charging points is sufficient. Finally, as a proof of concept of interoperability among systems, e-Roaming was demonstrated by using the ZET app to book a charging point at Eurecat premises and to handle a charging session. The interaction took place using Hubject e-roaming platform, ZET took the role of EMP and Eurecat took the role of CPO.

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.

Smart Energy management: The production of existing PV panels in Manresa office was monitored. All the energy is consumed in the building, even during weekend and holidays because the building has labs with equipment running 24/7. Eurecat management has decided to further invest on local RES and will extend the number of PV panels from 36 to 100 in the near future. Information on the energy use in the building is obtained from the energy meters (lighting, HVAC, other pluggable devices), information on the charging flexibility is obtained from the booking back-end and information on local RES availability is estimated using the PV parameters and location and historical records. Unfortunately, the weather service used did not provide irradiation, but UV index and cloudiness. An attempt to build a regressor model to link UV index, cloudiness and theoretical solar radiation was done, but the estimation was not very accurate. The charging of individual e-cars is calculated through the scheduler according to energy prices and energy mix. HVAC set-points were meant to be calculated for better energy balance, not affecting users comfort, however due to pandemic, energy efficiency was set aside and air quality and ventilation (natural and mechanical) had highest priority and no change in the set-points were allowed.

4.1.3 BCN.D3: St. Quirze e-bike sharing service

The measures implemented in this demonstrator are grouped in the following table (see D5.4-D6.3 for more details)

Measure groups	Measures
EV Fleet	• Shared EVs • Shared EVs integrated with public transport
Charging	• Private CPs • Flexible charging
Smart energy management	• Local RES • Local storage • Optimal and coordinated use of energy
Business aspects	• Payment for sharing EVs (*)

EV Fleet measures: The e-bikes (5) are available to a group of commuters working in Sant Quirze area. The bike station is located in the train station; it is not for exclusive use of train passengers, but its location targets mainly commuters. The service is offered by the townhall through the employers, at no charge, for a limited time period so that as many users can use the service. The key that was used to open the bike station was replaced by an app (the scanning of an NFC tag at the door by a registered user triggers the opening of the door). The app also is used to assign an e-bike to the user through the scanning of a QR code. This binding allows to monitor that the user fulfils the terms and conditions: does not exceed the town limit, returns the e-bike every day, … and also allows the user to keep track of their trips. The introduction of ICT tools enhances the fleet management, increases security and pave the way for scalability of the service.

Charging measures: The charging points in the e-bike station are meant to be used only to charge the e-bikes of the sharing services. However, the measure applied by GreenCharge consisted in installing new charging points with monitoring and controlling functionalities. In fact, in the station there are 5 charging points, that opens the door to open the station to users with their own bikes. That was consider that could take place in a later phase. The monitoring and controlling capabilities of each charging points enable to activate and de-

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.

activate the power supply individually, thus the charging process can be controlled according to the set points provided by the smart energy management system. The charging system was tested to charge the e-bikes sequentially rather than simultaneously.

Smart energy management measures: The measures included the installation of a PV panels on the station rooftop, an inverter and a stationary battery together with sensors to monitor energy consumption and production and relays to control the charging in the charging points. The stationary battery was needed because the typical usage is that users take the e-bike in the morning (8:00 – 9:30) and return the bike to the station in the afternoon (17:30 – 19:00), thus when the sun is shining and the PV panels produce energy, the bikes are not there to be charged. The sizing of the PV panels and the stationary battery enables the station to be self-sufficient. The coordinated charging process happens at night, when the bikes are back to the station. The optimisation criterium is to reduce as much as possible the use of energy coming from the public grid. Although the stationary battery can supply energy for a simultaneous charging of all the e-bikes, the strategy was to charge them sequentially to minimise battery wear/fatigue. The users do not book in advance as they do in BCN.D2, thus energy demand needs to be estimated based on usage profiles. Unfortunately, we didn't manage to collect enough data to train a load demand forecasting system. This is something that will be done as future work.

4.2 KPI's relevant for the Barcelona demos

The following table summarizes the KPI's relevant for the Barcelon demonstrators. The measures where they are relevant are presented. Being:

- M1: EV Fleet
- M2: Charging
- M3 Smart Energy Management
- M4 Business aspects

The evaluation of these KPIs will be presented in D5.5-D6.4.

Indicators	Demonstrator		
	BCN.D1	BCN.D2	BCN.D3
GC 6.1 Awareness level	M1+M3	M2+M3	M1+M2+M3+M4
GC 6.2 Acceptance level	M1+M2+M3	M2+M3	M1+M2+M3+M4
GC 6.3 Perception level of physical accessibility of service	M1+M2	M2	M1+M2
GC 6.4 Operational barriers	M1+M2	M2+M3	M1+M2+M3
GC 6.5 Relative cost of the service	M4		M4
GC 6.6 Shared EVs per capita	M1		M1
GC.5.1Number of EVs	M2	M2	M2
GC5.2 Number of CPs	M2	M2	M2
GC 5.3 Utilization of CPs	M2	M2	M2
GC 5.5 Charging availability		M2	
GC 5.13 Charging Flexibility	M2	M2	
GC 5.12 CO2 Emissions	M2+M3	M2+M3	M2
GC 5.10 Peak to average ratio	M3	M2+M3	M3
GC 5.14 Self-consumption	M3	M3	M3
GC 5.9 Energy mix	M3	M3	M3
GC 5.6 Average operating costs	M4		M4
GC 5.7 Capital investment cost	M4		M4
GC 5.8 Average operating revenue	M4		M4

5 Data collection

5.1 Implementation in manual and automatic mode

In order to calculate the KPIs described in section 4.2, data needed to be collected, either manually or using sensors or importing data from other services with data connectors. This information was stored with different formats in several databases (one per demonstrator) and then transformed into the GreenCharge research data format described in *D5.6 Open Research Data*. Most of these data will be made publicly available in Zenodo.

Manual data collection

The data manually collected relates to:

- Make and models of devices (e-bikes, HVAC, PV panels, …)
- Individual devices (instances of the make and models. i.e. 5 e-bikes of model X)
- Tariffs (definition of the tariff structure)
- Investment, operational and maintenance costs
- Feedback from stakeholders

The data collected manually has been stored in intermediate files (Excel files or text documents) before being translated into GC research data format.

The source of information is diverse: sometimes the information was stored in other systems, sometimes it was needed to ask the people to get this data, and sometimes it was needed to search for information publicly available on the internet.

The feedback from stakeholders is considered to be also a type of data manually collected. There had been interviews and surveys. In the case of on-line surveys, even if the data is collected automatically through a form, there is a manual processing of the results.

Automatic data collection

The data collected by automatic means relates to:

- Energy consumption and production
- Bookings
- Weather conditions
- Spot prices
- Energy mix

For energy consumption the data obtained directly from energy meters installed in the demonstrator in the implementation phase or from existing systems already in place (BEMS in Eurecat building). The readings of the energy consumption had been later converted into charging sessions, heating and cooling sessions, and main energy meter sessions as defined by the GC research format.

For energy production of the PV panels, the information has been obtained from the inverter and from a web portal provided by the inverter manufacturer. In the case of BCN.D2, the first approach was to collect data with high resolution (1-minute granularity) directly from the inverter but due to some discontinuity in the data collection and some big gaps, it has been complemented with the data stored in the Sunny web portal with 15-minute granularity. The data stored in the database is transformed into PV sessions.

The bookings for BCN.D2 are collected through the webapp. This information is meant to be used in the charging sessions, and for smart energy management.

The weather conditions are relevant to estimate PV production (BCN.D2, BCN.D3) and HVAC consumption (BCN.D2). They might be also relevant for the usage of the e-bikes in BCN.D3 (when it rains people may not use them). Forecast as well as current conditions are necessary. In the three demonstrators we have used Darksky meteo service. The same data connector is used and only the location used in the API request change.

For the case of BCN.D2, current weather conditions have been gathered from a weather station located on the roof of the building.

The information about variable tariffs is published every day by eSios[2] platform for the Spanish energy market. A data connector was implemented to pull this information daily. During the project the tariff scheme changed (in June'2021) that affected the id's of the information to be retrieved and caused some discontinuity in the data gathering process. Anyway, the historical information can be retrieved at any time.

The share of different generation technologies used to produce energy is publicly available for most European countries in Entso-e[3] portal. The information includes the amount of energy produced by each technology (gas, coal, biomass, …). The granularity depends on the TSO; in Spain it is provided hourly. For Solar and Wind technologies, also the forecasted production for the next day is provided. A data connector to pull this information using Entso-e API has been used. A similar information is provided also by eSios platform, since it is operated by the Spanish TSO. This information is used to calculate the CO2 emissions produced by the energy consumed from the public grid.

The following table summarises the mechanism used to collect each type of data in the demonstrators:

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
	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

[2] https://www.esios.ree.es/es/pvpc
[3] https://www.entsoe.eu/

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Category	Type of data	Collection method		
		BCN.D1	BCN.D2	BCN.D3
	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

5.2 Results of data collection

The data collection process has resulted in a big amount of efforts to solve challenges and lessons learned in interoperability and improvement of data connector development to make them as robust as possible.

The amount of data collected was affected by the number of users and the period that the demonstrator was in operation. It has not meet the initial expectations; however enough samples have been gathered to enable to produce results, either by extrapolation or using the simulator.

The following table summarises the data gathered by the three demonstrators.

Category	Datasets	BCN.D1	BCN.D2	BCN.D3
Individual devices	EVs	6	5 (only 2 regularly active)	5
	Charging points	1	3	5
	PVs		1	1
	Inverters		1	1
	Heating and cooling devices		1	
	Sensors	6	3	5
Logfiles	Bookings		-	

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	Charging sessions	399	80	5
	Heating and Cooling energy consumption		210 days	
	Background load consumption		210 days	
	PV production		380 days	
	Weather information		290 days	
	Spot prices for electricity		290 days	
	Energy mix		290 days	

5.3 Challenges

The main challenges encountered were described in D2.20 Technical Monitoring Report and Feedbacks (Barcelona). Since that report was produced very close in time to that one, basically the main challenges applied. There are included here with a revision. In severity order, the list of challenges include:

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

Following some details are given to help to understand them and to be considered in future developments.

1. <u>Lack of data</u>

It has been extremely challenging to put the demonstrators into operation. In fact, BCN.D3 has only worked for a very period of time with beta-testers. That has delayed the evaluation process, since data had been delivered late.

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: two different approaches were considered (B2C and B2B). 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 hybrid model is foreseen to be come into place in March 14, 2022 (beyond the scope of the project). Besides, and this is not directly related to COVID19, the number of EV drivers is quite low.

In the case of BCN.D3, the number of e-bikes is very low as well. It was not possible to run the demonstrator with real end users. However, in order to collect data similar as the one generated by normal usage of the service, some trips were done by members of the consortium, friends and family. This information is analysed to infer energy demand and to create profiles for scenarios to be simulated. There are several reasons for the

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delay. First, the lockdown, then the communication with the townhall was interrupted, and later the change in team members, especially in the townhall, the slowness of bureaucracy to get the terms and conditions approved and re-priorization of projects and initiatives.

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 a better protocol to foster communication flow among stakeholders needs to be worked out.

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.

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. Although everything was ready from GreenCharge we saw that the last administrative step to approve the terms and conditions by the local government was not taking place and we defined a Plan B, to gather data with beta-testers (friends and family of consortium members).

Finally, although the impact has been a way less important, the changes in the researchers and developer teams, in particular at Eurecat and Enchufing, 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. 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.

5. Interoperability among systems

In fact, in a project qualifies as an Innovation Action , 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,

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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.

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.

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6 Lessons learned

This section will update the set of lessons learned presented in D2.20 Technical Monitoring Report and Feedbacks (Barcelona) from the process of putting (or trying) the demonstrators in running mode and collecting as much data as possible for the evaluation of the measures put in place.

The learnings can be summarised as follows:

- 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 clearly state 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 too 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. The evolution of sales is uncertain due to a scalation in electricity prices that makes the EVs less attractive in terms of maintenance cost compared to 1 year ago, for instance. In addition, the economic crises caused by COVID19 and very recently the current and future consequences of Ukraine war may postpone the purchase of new vehicles.
- 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 and that budget and resources for maintenance needs to be allocated.
- 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.
- The context and environment change continuously and affects the plans. Flexibility to adapt to changes is required. To take an iterative approach with short iteration may help to keep the context more stable, however, ambitious changes require a mid- to long- term perspective. At design phase it is important to identify risks and what-if scenarios to define the roadmap for implementation and operation and make it more robust to changes, plan for checkpoints and use them to reconsider if makes sense to continue as planned or re-define some steps or goals. There is a trade-off between a very thorough planning phase to produce a robust and contingency-proof plan and the time invested in this phase to get the implementation ready for use and test as much as possible. Some disruptive events, such as a pandemic and its side effects that will last long after the pandemic will be eradicated could not be foreseen,

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7 Guidelines and recommendations for replicability and further development

According to the experience gathered during the design, implementation and operation of the pilot in Barcelona and the feedback from the of activities in the project, we can provide some considerations to be taking into account for replicability of the measures implemented or to extend the pilot in time or scope.

- **Multidisciplinary design team**: The services and measures to put in place for electromobility have effect on multiple stakeholders including end-users, either directly or indirectly. In the design phase it is very important to involve as many different stakeholders as possible to gather their views and to foresee side effects. It is important to consider not only stakeholders directly affected by the measure. For instance, it is important to hear the opinion of EV drivers, but also the opinion of non-EV drivers. Organise several focus groups or workshops to refine the design. It is important to start with a core group to prepare these workshops, but then extend it to a broader group. The workshops should be limited in time, but not too short (2 to 2.5 hours could be reasonable). Prepare for multiple workshops, to get into different levels of definition, from general ideas in the first iterations to fine details in the last ones.
- **Common (human) language building**: A multidisciplinary team is very useful to build a rich solution, but it also involves communication challenges. Stakeholders from different domains use different language and do not have the same level of knowledge of the different aspects. It is important to build together a common language as early in the project as possible and to shape the message to be understood by everyone. Frequent meetings, face-to-face or on-line, help to build this common language.
- **Common data model**: As important as language is for humans, data models and protocols are important for system interoperability. When choosing the systems and services, bear in mind the interoperability options they offer, the chances to include import/export functionalities and the capability to implement data connectors or data translators. Data plays an important role, thus take the time to define the data needed for operation and evaluation and make sure that these data can be accessed. Re-define the scope of the measure, the systems to be included or implemented or the evaluation methodology to adapt to the accessible data.
- **Technical support and supply chain:** The integration of systems has proven to be a challenge, even if it is stated that equipment used standard protocols. In the process of selection devices or services, be sure that the provider has a good technical support service either by own past experience or known reputation. It could be advisable to contact them to solve some doubts and see how they response. Also, when possible, get or buy a sample for testing before taking a decision. It is highly likely that you will need support in the implementation phase and only their technical support can solve some blocking issues. When taking the decision on a supplier, it is also important to analyse the company trajectory and roadmap. Apart from the initial purchase, additional components or updates may be needed in the future. If the supplier had disappeared by then or has discontinued the product, the implementation and operation can be highly disturbed. Regarding supply chain, we have learned from the COVID19 pandemic that China is the European (and worldwide) factory for electronic components, and a disruption in the production and transportation chain causes major effects. Extraordinary events cannot be foreseen or avoided, but it is wise to take a look at product availability (number of units in stock), production times and delivery times to avoid bottle necks or blocking situations.
- **Data collection and evaluation**: As mentioned, data is crucial. The definition of the measure to implement should be accompanied with the indicators to evaluate its performance. In turn, the calculation of the indicator requires data. A very precise definition of how the indicators will be calculated needs to be done. From this definition, the data necessary can be obtained. From this data needed the sources of information are derived and this input should go to the definition of the system architecture and the planning of actions for data collection, especially the information that is not collected automatically by sensors. We recommend to do some evaluations tests in a very early stage

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of the project, even if no real data is available or the data sets are very small. The reason for that is not to get meaningful values for KPIs to take decisions, but to test the whole process and identify any gap in the implementation phase.

- **Check points and re-planning**: Except if the measures are applied in a laboratory, the context changes continuously and affects the implementation, operation and evaluation phase. It is important to establish check points during all the phases to validate that even with the new context the plan and the scope is still valid. At a certain point in time, the decision taken were the best one that could be taken, but as the context evolve, they might be not. A good log on the decisions made and the reasons to reach those decisions will help in the decision-making process. If needed, replan some activities to avoid bottle necks as much as possible and be creative to find work-arounds (temporary or permanent). There is a trade-off between too many check points and too few. To have regularly meetings can be very time consuming, especially in phases where there is not much to report, however, to establish deadlines always is effective in pushing development forward.
- **Definition of roles and responsibilities**: To keep the work going, it is very important to define the role of each team member and assign clear responsibilities, according to skills and capabilities. Avoid as much as possible to assign a task to a group of people, there should be always a person leading the task, and the rest will support him or her. This will help to lose some tasks in "no man/woman's land'. Being said that, working as a team is the key to success and if one fails, the project fails. This is linked to the "flexibility" recommendation that follows. Sentences as "my part works" should be replaced "I have completed my task; how can I help?". The project is not an addition of parts that work but the integration of parts that all together works.
- **Flexibility**: As mentioned, the world keeps turning, and unlikely or unexpected events may occur. It is important to adapt to the new situation rather than keep trying to go on with an obsolete definition. Evenly, it is important to re-allocate resources or responsibilities and to work as a team, rather than to work in silos, every bound in the chain is equally important.
- **Resources allocation**: Bear in mind that assets may break and need repairing in any of the phases of the project (also during implementation phase), and that the operation phase requires also material and human resources. A shortage of resources during the operation phase could ruin all the work, for instance because no budget was allocated to repair a flat tire.
- **Documentation**: Team composition may change over time. It is very important to keep comprehensive record of all the information generated during the project, not only requirements and technical specifications, but also the decisions that were taken and the information considered for taking such decisions. As important as keeping the documentation, it should be findable, that means that it should be in a share space (with restricted access if necessary), but also it should be sorted in a logical way. For source code, there are many available tools (repositories) that supports team development; yet it is necessary to agree on some procedures and to tag versions.
- **Extended business model approach**: In Barcelona pilot, some demonstrators did not have an associated business model because according to the standard definition a business model always involved money exchange. We recommend using a broader definition of business model to take into consideration not only direct money flow but also indirect economic effects. For instance, an e-bike sharing service that helps to replace trips done by private fuelled cars by a cleaner mobility option, it also helps to reduce air pollution. Air pollution causes diseases that requires sick leaves and affect productivity, and premature deaths. Employers, the national health system and citizens benefit from that. In those cases, where the incomes are indirect and/or global, the orchestrator should be the public administration.
- **Public administration support**: As mentioned before, some business models may be not viable using the standard paradigm of money exchange because the benefit is spread among multiple stakeholders, while the expenses are not necessarily covered by the beneficiaries. In those cases, the support of public administration is needed. They can provide cover the expenses, provide funds or subsidise some business, ease the implementation of some measures by adjusting regulation or offering the use of public assets or spaces.

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- **Holistic approach for SUMP**: Electromobility should be taken into account in future SUMPs. However, electromobility is not just about mobility, and we recommend taking a broader scope and involve other departments instead or working in silos. For instance, mobility measures using electric vehicles need to pay attention of energy sources and charging infrastructure. At the same time, this charging infrastructure has to be located somewhere, meaning that construction regulation has to be adapted as well. Economic aspects for equity have to be considered as well, and the implementation of some measure may be linked to the economic situation of the region. Finally, mobility options also affect citizens health, thus social and health aspects should be addressed as well.

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8 Conclusions *and* Future Work

From the work carried out in Barcelona pilot and in collaboration with the rest of the tasks of the project, the following conclusions can be obtained:

- It has been possible to implement measures related to EV fleet, charging and smart energy management in Barcelona pilot after including ICT tools to gather information, monitor and control devices
- Business aspects have been analysed to find viable business models. One of them have been implemented. A broader definition of viable business model is needed when there is no actual money exchange
- EV users and the electromobility market share in Catalonia (and Spain) is still too small to be able to realise big scale pilots and attract private investment
- System interoperability is still a challenge and some critical information for smart energy management, such as state of charge for EV batteries is still not provided by manufacturers, even in the protocol is ready to receive it
- Data is crucial to evaluate the impact of measures but take informed decision, but the efforts to keep the data flowing should not be underestimated

In the future, some demonstrator will continue (BCN.D1, BCN.D2). The continuity of demonstrator BCN.D3 is uncertain, although the main concept maybe applied to a new rotatory parking facility open to citizens to park and charge their individual mobility vehicles.

For BCN.D2, further optimisation actions will take place, especially, when employees go back to the offices. For the moment, there are plans to increase substantially the solar capacity by adding new PV panels.

The evolution of the share of electric vehicles, and thus the need for more charging infrastructure, is uncertain at the moment. Traditionally, one of the selling points of EVs was that the cost per km and maintenance cost was much lower compared to ICE vehicles. Yet, charging in many public charging points were free. That has changed; Barcelona city have removed this incentive. Besides, the cost of electricity in Spain in November 2021 was 7-fold higher that the cost in November 2020. Currently, the cost is 10 times higher and may increase still further due to Ukraine war. In this case, also the cost of gasoline and diesel has increased.

The effects caused by Ukraine war are uncertain in the short- and mid- term. For the moment, the cost of energy has increased, and we have realised that we still are dependent of gas and petrol. That could foster a quicker change to sustainable energy sources in Europe territory or, could delay investments needed since funds will need to be used to cope with the humanitarian crisis.

At individual level, the economic crisis caused by COVID19 pandemic (one of the main Spanish ‘industry’ is tourism), the cost of electricity and the uncertain geopolitical situation may keep on hold purchasing decisions.

All in all, the outcomes of the project are promising, there is much room for energy management improvment and we are eager to exploit and improve the results in further projects to come.

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Members of the GreenCharge consortium

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

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