GREEN CHARGE

Supporting 'smart electric mobility' in cities

GreenCharge Project Deliverable: D1.4

Summary of Project Achievements

CIVITAS 2030
Sustainable and smart mobility for all

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CIVITAS 2030
Sustainable and smart mobility for all

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GREEN CHARGE

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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* (bikes, scooters, cars), *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 charge points, grid investment reductions, and policy and public communication measures for accelerating uptake of electromobility.

For more information
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Executive Summary

During the course of three and a half years, the GreenCharge project has proposed innovative solutions to help address the barriers to the wide uptake of eMobility. This deliverable presents the GreenCharge concept, approach and the main achievements in this regard.

In the GreenCharge concept, electric vehicles, charge management and local energy management work together to facilitate a transport system running on green energy. This requires the integration of the transport, building and energy sectors and is complex, in part due to the lack of standardisation. The GreenCharge *Reference Architecture* provides a full-fledged specification of the ecosystem for smart and green charging and acts as a blueprint guiding the creation of individual system realisations into a coherent ecosystem for eMobility. Recommendations for the standardisation of the necessary functionality and requirements for protocols are suggested.

The GreenCharge *business models* have been designed through participatory workshops and represented as multi-sided marketplace business models, instead of traditional "pipeline" business models. The business models cover innovative business aspects developed in the demonstrators as well as futuristic ones that are not feasible to demonstrate in the current state of practice.

The GreenCharge project has set up *demonstrators* in three pilot cities: Oslo (Norway), Bremen (Germany) and Barcelona (Spain). The demonstrators are complementary in maturity and conditions with regard to the transition to eMobility. Each demo is supported by business models and technology prototypes that realise a selective set of innovative features defined in the Reference Architecture based on the local context. Together the demonstrators have experimented with the concept of smart energy management that makes use of local Renewable Energy Sources (RES) for charging, the flexible sharing of the charging infrastructure and the flexible sharing of various kinds of EVs.

The GreenCharge *evaluation framework and tools* help establish knowledge (i.e., *evaluation results and lessons learnt*) about the implementation and the impact of the GreenCharge solutions in a scientifically correct way. The GreenCharge evaluation approach is based on an indicator framework built upon and extending the CIVITAS Evaluation Framework. The real-life demonstrators have been complemented by simulations to mitigate the limitations of the demonstrators with respect to size and complexity. The evaluation uses research data (automatically or manually collected) and has been supported by a KPI calculator, a simulator and two optimisers. New knowledge has been obtained through the evaluation results and lessons learnt from the demonstrations and simulations. The data collected from the pilots have been published as *open research data* to benefit the further research on the effects of eMobility in cities and other research.

GreenCharge has provided *recommendations and guidelines for integration of eMobility into Sustainable Urban Mobility Plans* (SUMPs) for city planners and policy makers. These include SUMP approaches with overall guidelines and best practice examples as inspiration for cities. In addition, recommendations for structuring multi-stakeholder investment in eMobility from business models perspective have been provided.

The GreenCharge project has completed a coaching programme with a group of Uptake Cities. With the transfer of the skills and knowledge gained in GreenCharge, individual Uptake Cities produced a graphical "roadmap" (*Uptake Cities Roadmaps*) tailored to their own specific needs towards the future eMobility in their own city. GreenCharge also suggests ways local authorities can further develop their roadmaps to integrate green energy aspects. For each aspect, GreenCharge has also scrutinised *innovation* in energy, charging and mobility in the "outside world" to facilitate development of its own results and to remain relevant throughout (and after) the project. This is reflected throughout each of the document chapters.

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List of Abbreviations

Table 0-1: List of abbreviations

Abbreviation	Explanation
API	Application Programming Interface
CPO	Charge Point Operator
DoA	Description of Action
EMP	Electric Mobility Provider
ESN	Energy Smart Neighbourhood
EV	Electrical Vehicle
KPI	Key Performance Indicator
MaaS	Mobility as a Service
NEM	Neighbourhood Energy Management system
OME	Original Manufacturer Equipment
RA	Reference Architecture
RES	Renewable Energy Source
SoC	State of Charge
SotA	State-of-the-Art
SUMP	Sustainable Urban Mobility Plan
V2G	Vehicle-to-Grid

List of Definitions

Table 0-2: List of definitions

Definition	Explanation
Architecture	The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution [IEEE 1471-2000].
Architecture viewpoint	View of the system addressing a particular set of concerns, targeting stakeholders with different backgrounds. For example, a context viewpoint describes the environment of the system, including system stakeholders and their concerns, while a component viewpoint describes the decomposition of the system into components, including interfaces, interaction and information.
Electric Vehicle (EV)	Electric vehicles use an electric engine and a battery to provide the needed energy. They include several types of vehicles: e-bikes (electric bicycles), e-scooter (electric scooters), e-car (electric cars), among others.
Key Performance Indicator (KPI)	An indicator used to quantify the impact of a measure.
Measure	Action, feature, or support implemented to improve sustainable mobility.
Optimiser	A component that maximizes resource efficiency. In GreenCharge, the goal of optimisation is to maximise the use of renewable energy.
Use Case	A list of steps defining the interactions between actors and a system to achieve a specific goal. Actors may be people and external systems.
Smart Energy Management	System adapting the use of energy to energy availability. May also take predictions of future energy availability and demand into account.
System of Systems	A collection of independent systems, integrated into a larger system that delivers unique capabilities.
Vehicle to Grid (V2G)	Capability of an electric vehicle to behave as a stationary battery, returning accumulated energy to the grid.

1 About this Deliverable

1.1 Why would I want to read this deliverable?

This deliverable summarises the achievements of the GreenCharge project. It has been produced at the end of the three and a half years project and helps to identify particularly relevant parts of the work undertaken. It serves as a shortcut to project findings and refers to project's publications for more details.

1.2 Intended readership/users

The intended readers are those who are interested in eMobility, from those who are concerned by policy and financial drivers (including policy recommendations in Sustainable Urban Mobility Plan, or SUMP) for eMobility, to those who are seeking knowledge on the technical implementation of smart and green charging. The intended readership therefore covers policy makers in local, national, and European levels of government as well as charging infrastructure and software designers for eMobility (and specifically those involve in individual modes of transport such as bicycles, cars and motorcycles).

1.3 Purpose and content

This deliverable presents the project achievements and its main results, focusing on results that can be taken forward after project end. It covers both technical results and policies (SUMP).

The following achievements are presented:

- The Reference Architecture
- Business Models
- Demonstrators
- Evaluations and Simulations
- Sustainable Urban Mobility Plan
- Uptake Cities' roadmaps

Common sections include target users, highlights, innovation context, lessons learnt, and recommendations for further work.

1.4 Main project deliverables

This report builds upon the project deliverables that describe the final project results and lessons learnt during the project period, in particular the following deliverables:

- D2.8/D2.15/D2.21 Final Report for Oslo/Bremen/Barcelona Pilot: Lessons Learned and Guidelines.
- D3.4 Final Business Model Designs.
- D4.2 Final Architecture Design and Interoperability Specification.
- D4.5 Final Version of Integrated Prototype.
- D5.3 Simulation and Visualisation Tools (revised version).
- D5.5/D6.4 Final Result for Innovation Effects Evaluation/Stakeholder Acceptance Evaluation and Recommendations.
- D5.6 Open Research Data.
- D7.1 GreenCharge SUMP eMobility Approach.
- D7.2 Recommendations and Guidelines for Integrating Electric Mobility into SUMPs.
- D7.3 Lessons Learned from Roadmap Development in Uptake Cities.

These deliverables can be downloaded from the H2020 GreenCharge community on Zenodo.[1]

Unsplash / Jenny Ueberberg

1 https://zenodo.org/communities/h2020-greencharge

1.5 Other projects and initiatives

During the course of GreenCharge, many opportunities were taken to identify the existence of other projects and discussions examining similar topics to GreenCharge. This formed part of the Innovation Management role and also through the coordination of liaison with CIVITAS. These opportunities turned out to be many and varied, and without a specific Coordination and Support Action directed to eMobility, were impossible to track and fully maximise on an ongoing basis.

However, Table 1-1 summarises some of the projects working in the field that the reader may also find useful researching. More specific examples on innovation from outside of the project are also showcased throughout this report, demonstrating that GreenCharge is by no means operating in a vacuum nor has exclusive focus on the topics covered.

Table 1-1: Related projects in the field of eMobility

- ASSURED
- BSR Electric
- CityxChange
- CleanMobilEnergy
- eCharge4Drivers
- Efficience
- eHubs
- Elaad
- Electrific
- "Electric Mobility Europe" projects (such as
  - Electric Travelling and
  - EVRoaming4U)
- ELVITEN
- e-Mob
- eMobicity
- EMopoli
- EnerNETMob
- EV Energy
- INVADE
- MEISTER
- MySmartLife
- Neon
- Ready
- SEEV4CITY
- Sharing Cities
- SIMPLA
- "Smart Cities" projects (such as
  - Grow Smarter)
- SmartenCity
- Smarter Together
- Solutions Plus
- Stardust
- USER CHI
- Zenmo


Pixabay / Nitish Thakur

2 Project vision and overall approach

GreenCharge's vision is of an all-electric e-mobile future where people share pools of personal vehicles (bikes, cars, scooters) without concerns about vehicle availability or charging opportunities, in a well-functioning and financially viable ecosystem of users, service providers and authorities. Several barriers though make it difficult to achieve this vision:

- Many people in Europe lack easy access to a charge point at or near their home or work. Drivers also fear that charge points are not available on arrival at a charge station.
- While drivers wait for an improvement of the charging infrastructure before buying EVs, charging providers wait for more users before investing in provision of charging infrastructure.
- A shift to an e-mobile future may lead to huge peaks of demand on the electricity network, potentially requiring major upgrades of the energy infrastructure, both locally and on a wider scale – including the provision of new sources of renewable energy to help supplement and decarbonise the grid.

All these factors have evolved over the course of the GreenCharge project, as the number of public charging stations in Europe has increased from 154 000 in 2018, the time of the European Commission issuing the call for proposals on this topic, to more than 285 800 at the end of the project beginning of 2022[2], with predictions of 1.3 million public charging stations by 2025 and 2.9 million by 2030.

In the GreenCharge concept, electric vehicles, charge management and local energy management work together to facilitate a transport system running on green energy. Users of electric vehicles get charging support, and peaks in the power grid and grid investments are avoided through a balance of power. When many vehicles are plugged into the grid around the same time (e.g., on returning home from work), the energy management balances demand with available supplies. Supplies from local renewable energy sources and batteries in connected vehicles not in use may also be utilised. The concept also includes viable business and price models rewarding charging behaviour contributing to peak reductions. The transition to a greener society requires less consumption and more sharing, also sharing of EVs. Due to charging, EV sharing, and fleet management is however more complex than traditional fleet management, a challenge also addressed in GreenCharge.

This requires the cooperation of homeowners/occupiers/managers, energy providers, local authorities and transport companies, and a heightened awareness of energy management challenges at a neighbourhood level outside of the energy domain (as effectively explored and explained in the GreenCharge project).[3]

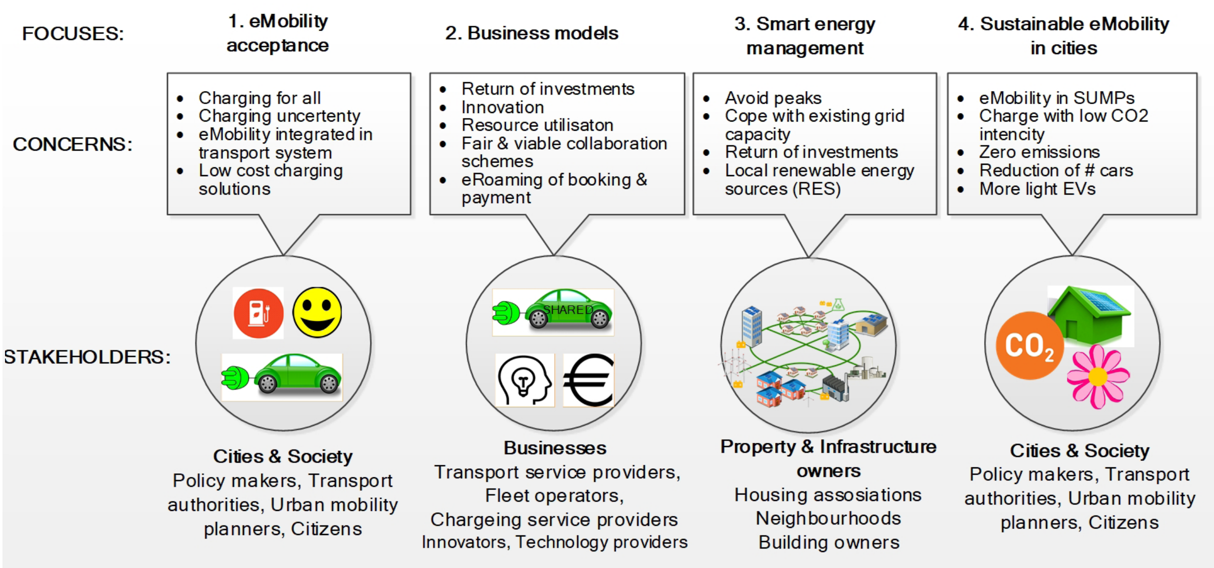
To assess the GreenCharge concept, the project set up concept and technology experiments, known as "demonstrators", in three pilot cities: Oslo (Norway), Bremen (Germany) and Barcelona (Spain). The lessons from the project are derived from these demonstrators.

Stakeholders and concerns: To realise an innovative charging infrastructure as envisaged, an integrated approach is necessary, ensuring the participation of a wide range of different stakeholders, honouring their concerns and enabling the collaboration of the different technology systems they operate. An overview of stakeholders and their concerns is shown in Figure 2-1.

2 www.statista.com/statistics/955443/number-of-electric-vehicle-charging-stations-in-europe

3 www.youtube.com/watch?v=tsBA8vKGBik&list=PLv-mhCFisOsXBFXpU1UpELWBgx3KfnuIU&index=9

Figure 2-1 Stakeholders and concerns of the charging infrastructure



Innovative use cases for smart and green charging: To further illustrate the GreenCharge concept, an initial set of innovative use cases were defined, that exemplify how technology and business models can work in typical challenging situations. Seven use cases were sketched:

- **Charge planning and booking**: Based on a trip plan set up by the driver, a charging plan is derived, and necessary charge stops are booked. The plan is updated to adapt to unforeseen events during the trip.
- **Charging at booked charge station**: The driver gets navigation support to identify the booked charge point. Charging is managed according to the booking constraints and in collaboration with the Neighbourhood energy management system of the neighbourhood in which the charge station is located.
- **Booking enforcement**: In order to avoid other cars to block booked charge points, drop-in customers get information about the availability/non-availability of charge points, and are requested to specify the time-slot they will be parked.
- **Charging in buildings/places with common internal grid and parking facilities (at home, at work, at shopping malls or public charging stations "along the road", etc)**: Rather than charging immediately after connection, the ESN energy management system schedules the charging according to the requested amount of energy and the expected departure time (provided by the driver), and state of charge at arrival. Locally produced electric energy is exploited as far as possible, while also considering other tasks that need electric power in the neighbourhood.
- **Vehicle to Grid (V2G)**: If the driver allows, the neighbourhood energy management system may discharge the battery of connected EVs temporarily to optimise the overall performance of the ESN, as long as the requested energy is charged at the expected time of departure.
- **Reacting to a Demand Response request**: In response to demand response requests from the public grid, the neighbourhood energy management system reschedules already scheduled flexible loads and/or exploits local storage resources (including V2G) to satisfy the request.

- **E-Mobility in innovative 'mobility as a service' (MaaS) offerings**: An EV fleet-based service is used to make more efficient the use of transport and parking infrastructure. Users get access to the cars of the fleet via electronic reservation and access. It is necessary to provide cars with sufficient battery charge for the planned trip. The fleet management system provides charge planning information to the neighbourhood energy management system.

Because of technology limitations, lack of standardised APIs to the different integrated technology systems and the complexity of implementation and deployment, the innovative use cases are only partially realised in the demonstrators. The functionality of all use cases is however described in more details in the GreenCharge Reference Architecture (see Section 3). After gaining better insight in the available technologies, a set of measures[4] related to the use cases were introduced, realised and evaluated in the demonstrators (see Section 5). GreenCharge has also developed a hybrid evaluation approach where the evaluation of real cases can be extended with the simulation of new use cases. Some of the use cases that could not be realised were simulated, e.g., V2G and ESN are simulated.

Energy Smart Neighbourhoods: Energy Smart Neighbourhoods (ESN) play a key role in the GreenCharge vision. An ESN aggregates energy consuming elements of the built environment, including buildings and local energy production and storage facilities. A neighbourhood energy management system coordinates and controls the energy use and the use of local storage to optimise the utilisation of locally produced energy and to reduce peak loads on the public grid.

The charging of electric vehicles is by nature flexible since the vehicles often are connected for longer periods than are needed for charging. This is beneficial in several ways. The batteries can be charged when the total energy demand is low, when the price is low, or when there is surplus energy from PV panels. In addition, EV batteries can be used as temporary energy storage that can be transferred to the grid (V2G) or used in case of demand peaks in the neighbourhood thus enabling even more flexibility. The flexibility is crucial. By integrating the charge management within a surrounding energy smart neighbourhood, charging power demand and the associated flexibility can be coordinated with the other power demands of the neighbourhood and aligned with the availability of local RES.

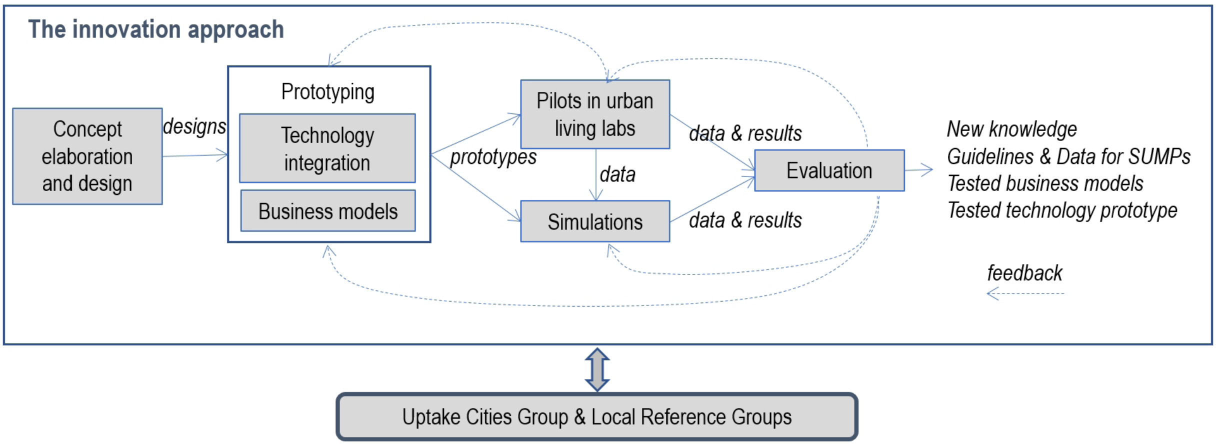
Business models: GreenCharge is not solely about technology. Good business models are needed to ensure adequate financial reward for investors and prices that consumers and authorities can afford. Therefore, the project also proposed and tested business innovations that strengthen the exploitation of the technological innovations.

EV-charging is still subsidised which is unsustainable in the long run. Viable business models will be those models that consider the sharing economy concept. These are among others sharing excess energy from local renewable energy sources, new services for flexible charging and parking, EV sharing (including e-car, e-bike, e-scooter) and revenue from RES. A number of such business models were developed for the demonstrators in Barcelona, Bremen and Oslo, and they were not just about the money flows. The business and price models were also designed to encourage the desired behaviour, using for instance rewarding flexibility of charging and eco-driving of shared vehicles, and penalising the blocking of charge points.

Overall approach to demonstration and evaluation: The project overall approach is depicted in Figure 2-2. Starting from the concept, technology prototypes were realised by means of a combination of new developments, refinements and integration of commercial systems owned by project participants, and business models developed involving various stakeholders. To evaluate the solutions, the prototypes were tested in in real life demonstrators in the three pilot cities (Oslo, Bremen and Barcelona). Further, the analysis of data from the field was complemented with simulations based on data collected from the demonstrators.

4 The term measure is adopted from the CIVITAS evaluation framework. A measure denotes an action or a feature implemented to improve sustainable mobility.

Figure 2-2 The iterative innovation approach

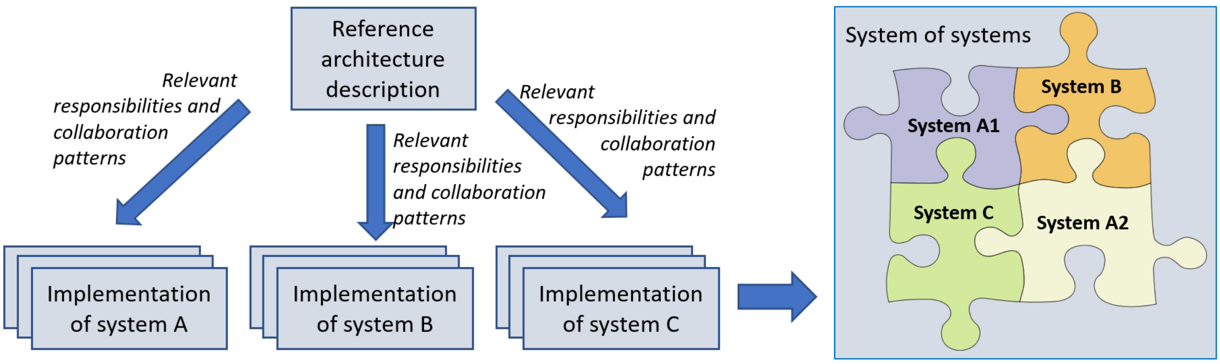


GreenCharge in a wider context: The project has been guided by the direction of policy and guidance at the EU level. This has sought to increase the proportion of electric vehicles, as well as support the overall decarbonisation agenda. The penetration of electric vehicles, resulting from strong policy support, in our pilot city of Oslo demonstrates a possible vision of the future which could sweep across Europe. Notwithstanding this, uneven and extremely slow progress exists in other parts of Europe. Whilst (with informed procurement) these areas can leapfrog to the latest innovations, developed through the experiences of pioneer cities, development scenarios should assume they may start with smaller scale and independent solutions. Implementation will need to be coupled with a growth in understanding of the technological possibilities (and their pitfalls), which will still be fluid for some time. GreenCharge acknowledges that it exists in a context of rapidly development on the technical component and part system side, yet slow development on the cross sectorial integration side, particularly during the time the project has been in a live stage.

Pixabay / Trinity Elektroroller

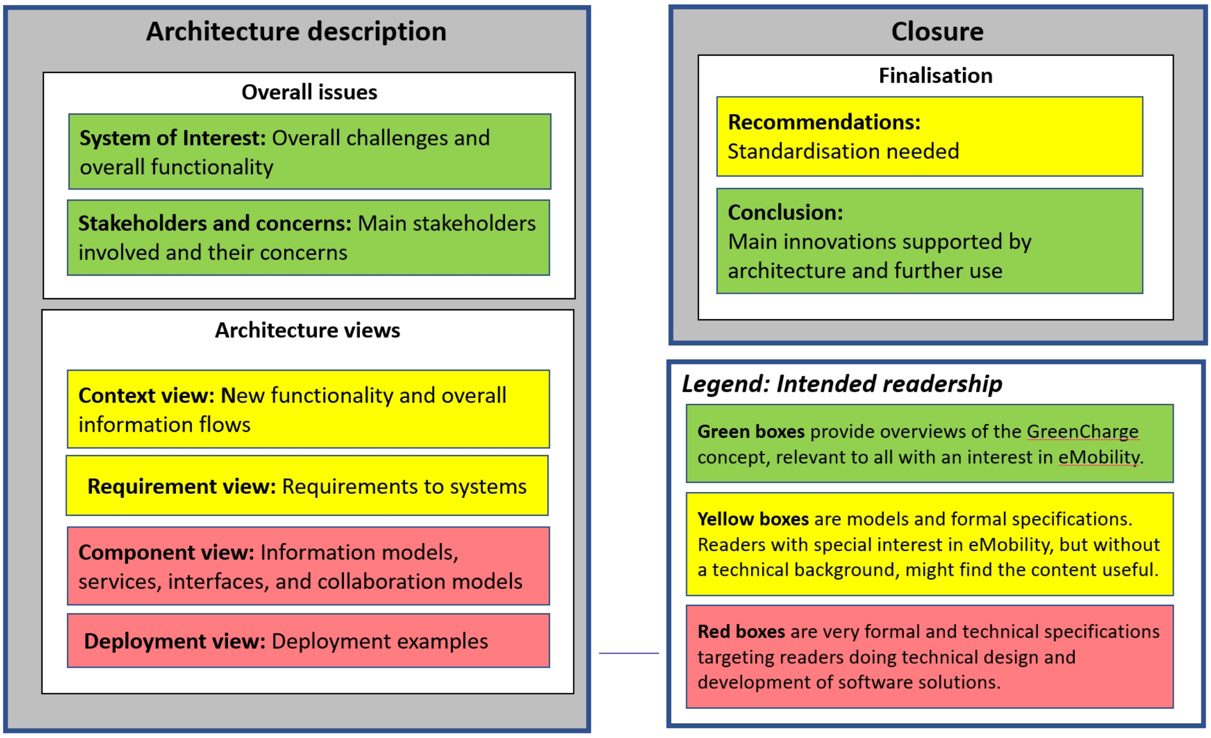
3 Reference architecture

3-1 The role of a reference architecture description (source: D4.2)



The GreenCharge Reference Architecture provides a full-fledged specification of the ecosystem for smart and green charging. This means that the architecture is a blueprint guiding the creation of systems or system components contributing to the GreenCharge concept. The intention is to support deployment and further exploitation outside the project. The architecture provides a common understanding of the concept and supports the integration of systems into the ecosystem in a well-defined way (Figure 3-1) so that the systems together create the jigsaw puzzle that realises the GreenCharge concept.

Figure 3-2 Content of the GreenCharge Reference Architecture and intended readership (source: D4.2)



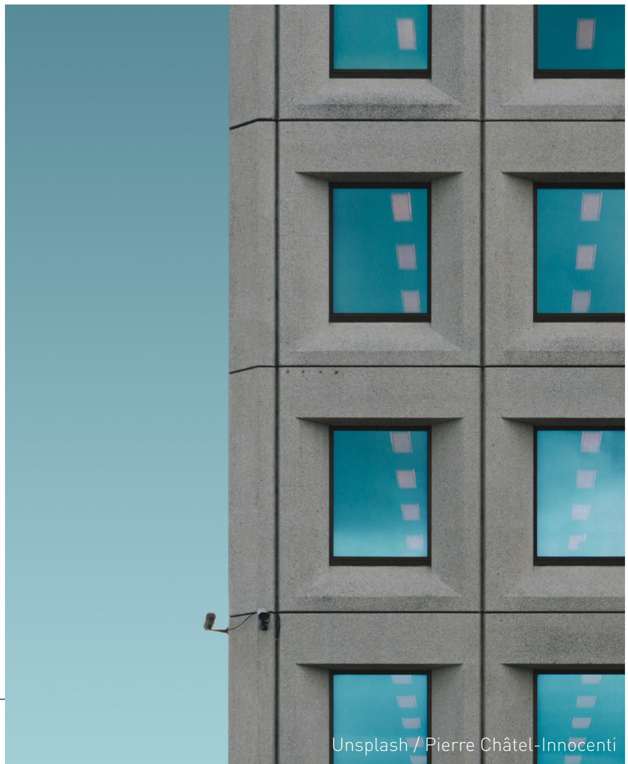
Target users:
The Reference Architecture includes descriptions at various levels of technical details relevant to the ecosystem, as illustrated in Figure 3-2, and it may serve different types of stakeholders as indicated by the colours. The green and yellow boxes are intended for stakeholders who are interested in a deeper insight into smart and green charging. Policy makers can for example benefit from this understanding and get a better position to influence the transition towards sustainable eMobility. Commercial actors within eMobility can get a better understanding of the role they can play and obtain input on the requirements to their system components and services/products. The yellow and red boxes are intended for technology providers who plan to design and implement smart and green charging. They may use the architecture as input to their software engineering processes.

Highlights:
The Reference Architecture includes overall issues, architecture views, and a closure part, as illustrated in Figure 3-2. The *overall issues* part describes the challenges addressed and the scope of the intended system. It also defines the stakeholders involved and their concerns and motivations for a change towards green and smart charging.

The *architecture views* address smart and green charging from different perspectives using models and diagrams with standard software engineering notations. The context view describes the functionality needed by the stakeholders involved. It requires less technical knowledge (yellow category). Other diagrams are formal technical specifications with details for software implementation (the red category). For example, the component view with an information model specifying information to be exchanged, and interfaces and collaboration model for interoperability. Some deployment view examples specifying the realisation of GreenCharge demonstrators are provided. Deployment views describe the mapping of parts of the architecture into physical systems.

Innovation context:
To our best knowledge, there is no established reference architecture for eMobility integrated with smart energy management. Some ongoing projects are working on architecture for specific aspects, e.g., the evRoaming4EU[5] project focuses on roaming services for charging EVs. Our work fills this gap and provides a blueprint for the design and implementation of eMobility solutions for the integration and interaction between systems provided by different stakeholder in the field. The scope of the Reference Architecture focuses on the integration of smart charging and smart local energy management, and additionally covers roaming services and sharing of CPs and EVs. In addition, our work provided input to standardisation with recommendations regarding where standardisation is needed and how to realise it.

Many of the innovative use cases proposed by the GreenCharge concept are difficult to realise due to the lack of standards. The Reference Architecture provides recommendations regarding standardisation with references to the architecture parts that can be used as input to the standardisation.



Unsplash / Pierre Châtel-Innocenti

5 www.evroaming4.eu/news/the-next-e-mobility-architecture

Lessons learnt:

The Reference Architecture addresses the integration of systems into a system of systems covering the mobility, building, and energy sectors. The work on the deployment view for the demonstrators confirms that the interfaces defined in the architecture are needed and the relevance of the functionality described. No single demonstrator demonstrates everything, but altogether the demonstrators cover almost all relevant aspects in various degree. However, the aspects of V2G and a full-fledged ESN could not be demonstrated in real life due to regulatory and practical constraints at this stage of technology maturity and societal acceptance.

The lessons learnt from the GreenCharge demonstrators and the architectural work indicate the aspects regarding eMobility and charging that are missing in current standardisation:

1) the integration of charging in local energy management,
2) data collection from EVs and EV fleets, and
3) advance booking of charging.

Standardisation recommendations are provided in the Reference Architecture addressing the required use cases (functionality), information models, and protocols. This would help drive the cooperation between stakeholders in the system and allow innovators to fully deploy the GreenCharge concept.

Further work:

The GreenCharge Reference Architecture embodies knowledge gained during GreenCharge project and supports the further work towards a full and sustainable electrification of the transport domain. Further work is however needed:

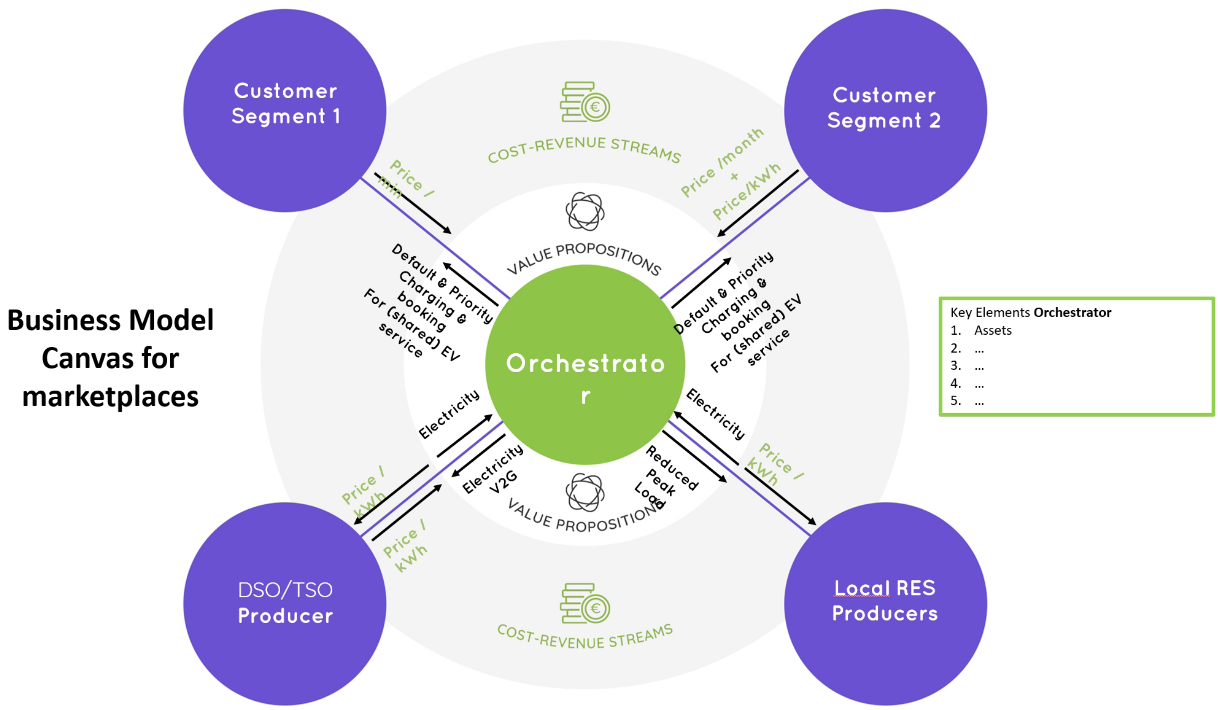
- *New technical solutions* must be established based on the principles outlined in the Reference Architecture to ensure that they can operate in the ecosystem for smart and green charging. The technical solutions must also be accompanied by viable business models ensuring economic sustainability.
- *Open standards* for easy and efficient integration of systems and access to the data needed must be established and deployed. The recommendations provided by the architecture are intended as input to this work.

More information:

- D4.2 Final Architecture Design and Interoperability Specification.
- Marit Natvig, Shanshan Jiang, and Svein Hallsteinsen. *Stakeholder Motivation Analysis for Smart and Green Charging for Electric Mobility*. WAINA 2020, vol 1150, pp. 1394–1407, 2020. Springer, Cham.
- Shanshan Jiang, Marit Natvig, Svein Hallsteinsen and Karen Byskov Lindberg. *Lessons Learned from Demonstrating Smart and Green Charging in an Urban Living Lab*. AINA 2022, LNNS 451, pp.1-13, 2022.

4 Business models

Figure 4-1 Business model canvas for marketplaces used for representing the designed business models (source: D3.4)



Viable, green and circular business models are needed to facilitate the large-scale deployment of charging infrastructure and charging services and to lower the barriers to wide-scale adoption of EVs. The GreenCharge project has designed and tested a number of innovative and collaborative business models to support viable business cases for EV charging with renewable energy in various contexts. These include selected business models demonstrated in the pilots and futuristic business models.

Target users:
The business model designs are relevant for all actors involved in the transition to zero emission mobility (EV user, fleet operator, charging service provider, roaming provider, micro- /smart grid provider, charge point operator, city authority, community or neighbourhood, etc). In particular, decision makers may find possible business model designs fitting for their organisations or use the tools or process description for design of their own innovative business models.

Highlights:
The GreenCharge innovative business models are inspired by ideas from the sharing economy, showing how to generate, use and share the additional capacity of private renewable energy sources (RES), private charging facilities and the batteries of parked EVs in ways that benefit all involved, not only economically, but also socially and environmentally.

The business model design has followed a participatory business modelling methodology involving all relevant actors. Workshops using Business Model Innovation games were carried out in the pilot sites with project partners and local reference groups to gain input on needs and requirements as well as feedback to the business model innovation process.

The business models are represented as multi-sided marketplace business models, instead of traditional "pipeline" business models. The business models are depicted in a canvas (Figure 4-1) where the stakeholders are connected via an orchestrator, and the value exchange between stakeholders is visualised. Among the questions asked and addressed are what are the forces that prompt, satisfy or incentivise different stakeholders to play their part in making the system of systems (as set out by the Reference Architecture, see Section 3) function completely and successfully. These are the terms on which the "orchestrator's" overall business model or system, succeeds or fails.

The viable business models are scalable, green and circular (use of locally produced renewable energy). Price levels for business models used in the demonstrators were decided with stakeholders involved to represent their values. Such values are not necessarily restricted to money. For example, a housing cooperative acting as the orchestrator of the ecosystem aims at reducing its investment cost as well as reducing the energy costs for residents. The innovative business models also aim at stimulating the desired user behaviour (e.g., encouraging sustainable/eco-driving or flexible charging).

The business models designed in GreenCharge cover various innovative business aspects (see Table 4-1). Some of these have been demonstrated in pilot cities (denoted as "D"), and information from relevant demos can be found in Section 5. Some of these are conceptual and cannot be demonstrated in the current state-of-practice, which are future business model designs that represent a vision (denoted as "F"). Some "futuristic" business models also elaborate on those that are demonstrated.

Table 4-1: Overview of the innovative business aspects in the business model designs

Innovative business aspects	Type of model D: demonstrated F: futuristic	EV charging	Smart energy management	EV or CP sharing	Promoting desired behaviour
Rewarding prosumers in ESN	D, F		X		
Rewarding lower peaks in ESN	D, F		X		
Rewarding flexibility in ESN	D, F	X	X		X
Penalizing priority in ESN	D, F	X			X
Payment for shared CPs	D, F			X	
Penalizing blocking of CP	D, F			X	X
Rewarding eco-driving	D				X
Fair distribution of costs for sharing in ESN	F	X	X	X	X

Lessons learnt:
The iterative business model innovation process for the implementation and testing of the demonstrators showed that one business model for all stakeholders per demonstrator represented as a multi-sided marketplace business model is a better business model design than a business model per stakeholder.

Such a multi-sided marketplace connected by an orchestrator simulates collaborations and maximise value for all stakeholders. The business and price models should be designed in collaboration with all partners involved. Producers and customers of energy need to receive a fair price in an innovative business model.

Financial viability in the exploitation of innovative solutions or technologies has been a key topic in

GreenCharge, and the extent to which eMobility is considered to be a "sustainable" mode of transport worthy of public subsidy (alongside traditional green forms of transport such as public transport, walking and cycling in many cities) remains variable. In many cases, incentives for eMobility are unstable and are often still in their early stages of development and maturity, with unclear transition processes. Some business models still require the scale of operations, which are dependent on mass moves away from the fossil-fuelled car) not yet achieved in many cities, for example in the support of charging systems for shared or private e-bikes.

Further work:
Currently, the switch from private to shared ownership of vehicles is not fully incentivised or realised in the transition to electric mobility as would have been envisaged in policy visions. New business models should go further from the traditional focus of economic sustainability and support behavioural changes. For example, economic incentives can be used to encourage EV users to provide the flexibility needed, to book charge points and energy in advance, and to use shared EVs. The use of technology in combination with such business models must be further explored.

More information:

- D3.4 Final Business Model Designs
- D8.5 Viable Business and Replication Plans
- Beniamino Di Martino, Dario Branco, Luigi Colucci Cante, Salvatore Venticinque, Reinhard Scholten & Bas Bosma. *Semantic and knowledge based support to business model evaluation to stimulate green behaviour of electric vehicles' drivers and energy prosumers*. J Ambient Intell Human Comput (2021).

Innovation context:
During the course of GreenCharge, a number of external reference points have emerged which have sought to further analyse and expand our knowledge of business model requirements for electric mobility charging.[6] These have been discussed with Uptake Cities during webinars (for further background, see Deliverable 7.3). These further studies reaffirm the importance of the multistakeholder perspective, and acknowledging the different values (monetary, or non-monetary – or indirectly monetised) that exist within the charging system. It is recommended that the reader considers Deliverable 8.5 on the GreenCharge concepts and other work alongside should it require further insights on business model challenges, options and solutions. The mobility context has been heavily disrupted over the lifespan of GreenCharge, with many new models of transport provision being introduced, promoted, and trialled on an increased scale (e.g., ride hailing, micro mobility), but limited sustained return on investment generated or maturity of continued service provision being achieved in many cases. However, improved attention on the requirements of stakeholders (such as public authorities, in the use of public space) and technological advancements (e.g., logistics of vehicle charging and swapping) have been already evident in these few years, as longer-term arrangements for sustainable operations are put into place.

6 e.g. Hall, S, Shepherd, S and Wadud, Z (2017) The Innovation Interface: Business model innovation for electric vehicle futures. Report. University of Leeds, Leeds, UK. https://eprints.whiterose.ac.uk/111115/1/11167_SEE_electrical_vehicles_report_WEB.pdf

5 Demonstrators

In order to fine-tune and evaluate the GreenCharge concept and technology, demonstrators were set up in three pilot cities: Oslo (Norway), Bremen (Germany) and Barcelona (Spain). The demonstrators were defined to leverage the complementarity in maturity and conditions with regard to the transition to a more sustainable transport system in the three pilot cities. They are therefore, to some extent, reflective of the many and varied conditions found across Europe in this respect. Together the demonstrators have experimented the concept of smart energy management that makes use of local RES for charging, flexible sharing of the charging infrastructure and flexible sharing of various kinds of EVs. In Oslo a particular focus has been set on providing cost efficient home charging facilities for inhabitants living in blocks of flats, in Bremen car sharing and use of stationary batteries to balance peak demand from charging, and in Barcelona on light (L-category) EVs.

A set of demo cards that summarise the purpose and the features of the different demonstrators are included below (Figure 5-1 - Figure 5-7). The demonstrators target different user groups and address different challenges. They combine various state-of-the-art features with innovative features. These innovative features are described in more details later in this section.

Figure 5-1 Oslo demonstrator: Charging in an Energy Smart Neighbourhood (Oslo D1)

OSLO demonstrator: Charging in an Energy Smart Neighbourhood

GREEN CHARGE

www.greencharge2020.eu

What: Cost efficient home charging for residents in a housing cooperative through the establishment of an Energy Smart Neighbourhood.

Why? All new cars shall have zero emissions by 2025. However, the charging capacity is limited for drivers living in apartment blocks or flats.

Our aim: To guarantee enough energy for residents in flats using existing grid capacities and to maximize the use of renewable energy.

Target groups:

- Residents in flats using electric vehicles
- Operators of charging points
- Enterprises, communities, housing cooperatives, other companies (B2B)

Innovative features:

- Booking of charging
- Flexible charging
- Optimal and coordinated use of energy
- Business models for
  - rewarding flexibility
  - penalizing priority
  - rewarding energy prosumers
  - rewarding low peaks

Enabling features (state of the art):

- Private charging points
- Priority charging
- Local renewable energy from 70kWp solar panels
- Stationary energy storage of 50kWh

Contributors:

- FORTUM (charge point operator)
- ZET (eMobility Provider)
- ESMART (Energy Management System)
- OSLO (facilitator)
- SINTEF (project leader)

2020 CIVITAS This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769016.

Figure 5-2 Oslo demonstrator: Book a charger before your visit! (Oslo D2)

OSLO demonstrator: Book a charger before your visit!

www.greencharge2020.eu

What: 4 charging points available to the public, in drop-in or booking modes, at the property of Røverkollen housing cooperative in Oslo.

Why? All new cars shall have zero emissions by 2025. The available charging points outside of the city centre are limited and lack booking features.

Our aim: Provide charging facility for visitors and neighbours, and to employees of the nearby school and users of the sports facility (football field).

Target groups:

- Users: Visitors and general public with electric cars.
- Uptake groups: Enterprises, community organisations, housing cooperatives, taxis, other companies (B2B)

Innovative features:

- Booking of charge point
- Business models for for penalizing the blocking of charge points

Enabling features (state of the art):

- Roaming – independent access to chargepoints
- Shared charging service with general access.

Contributors:

- FORTUM (charge point operator)
- ZET (eMobility Provider)
- Hubject (Roaming Operator)
- OSLO (facilitator)
- SINTEF (project leader)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769016.

Figure 5-3 Bremen demonstrator: GreenCharge@work (Bremen D1)

Bremen demonstrator: GreenCharge@work

www.greencharge2020.eu

What? Commuters receive re-charging from their company's power grid, which is supported by photovoltaic energy source and storage in used EV-batteries.

Why? An increasing number of employees will buy electric vehicles (EVs) and wish to recharge during working hours in addition to the company's fleet of eCars. However, the power grid capacity is currently limited.

Our aim: To realize smart and cost-efficient charging for both commuters' EVs and fleet of eCars - respecting a pre-set power limit of the local grid.

Target groups:

- Commuting owners of EVs
- Enterprises
- Communities supporting sharing of eCars

Innovative features:

- Booking of charge points
- Energy management
  - Peak-shaving capability
  - Automatic overnight reloading of stationary used battery storage

Enabling features (state of the art):

- Private and company fleet EVs
- Storage in used EV-batteries
- On-site PV energy supply
- Priority charging

Contributors:

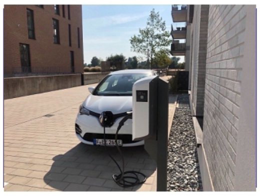
- PMC (charge point operator)
- HUBJ (e-roaming)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769016.

Figure 5-4 Bremen demonstrator: eCar sharing (Bremen D2)

Bremen demonstrator: eCar sharing

www.greencharge2020.eu



What: eCar sharing is promoted in an urban environment via an enhanced booking APP.

Why? Car sharing contributes to the reduction of private cars in an urban environment. The connection to public transport is foreseen to increase user acceptance.

Our aim: To develop eCar sharing as part of MaaS (Mobility as a Service) via a multi-mobility APP that can be used by any citizen.

Target groups:
- Residents in a defined neighbourhood of car sharing station (B2C)
- Housing cooperatives (B2B)
- Fleet managers (B2B)

Innovative features:
- Enhanced eCar Sharing APP
- Remote registration + license validation
- Keyless vehicle access
- Possible integration of CarSharing into MaaS via API

Enabling features (state of the art):
- In-vehicle System
- Booking APP
- Shared electric cars
- Open IT–infrastructure to share electric cars in MaaS-Platform

Contributors:
- ZET

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769016.

Figure 5-5 Barcelona demonstrator: shared electric scooters with battery swapping (Barcelona D1)

Barcelona demonstrator: shared electric scooters with battery swapping

www.greencharge2020.eu

What: Smooth and energy-efficient sharing of electric scooters using battery swapping and smart energy charging strategies.

Why? Electric vehicle sharing operators are struggling to keep operational costs on a budget to assure business profitability.

Our aim: Enhance fleet management in terms of reduction of energy-related costs by optimising battery charging, incentivising eco-driving and selection of dropping off locations.

Target groups:
- Users of electric mobility services such as sharing services for scooters or motorbikes
- Light electric vehicles sharing operators with swappable batteries

Innovative features:
- Link trip demand with charging needs
- Optimal use of energy for charging
- Business models for rewarding eco-driving based on in-vehicle sensor information

Enabling features (state of the art):
- Fleet of sensor-fitted electric scooters
- Charging through battery swapping
- Bind vehicles need with charging strategies
- Involvement of users in energy savings

Contributors:
- Motit (sharing operator and fleet manager)
- Eurecat (energy management)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769016.

Figure 5-6 Barcelona demonstrator: charging at work (Barcelona D2)

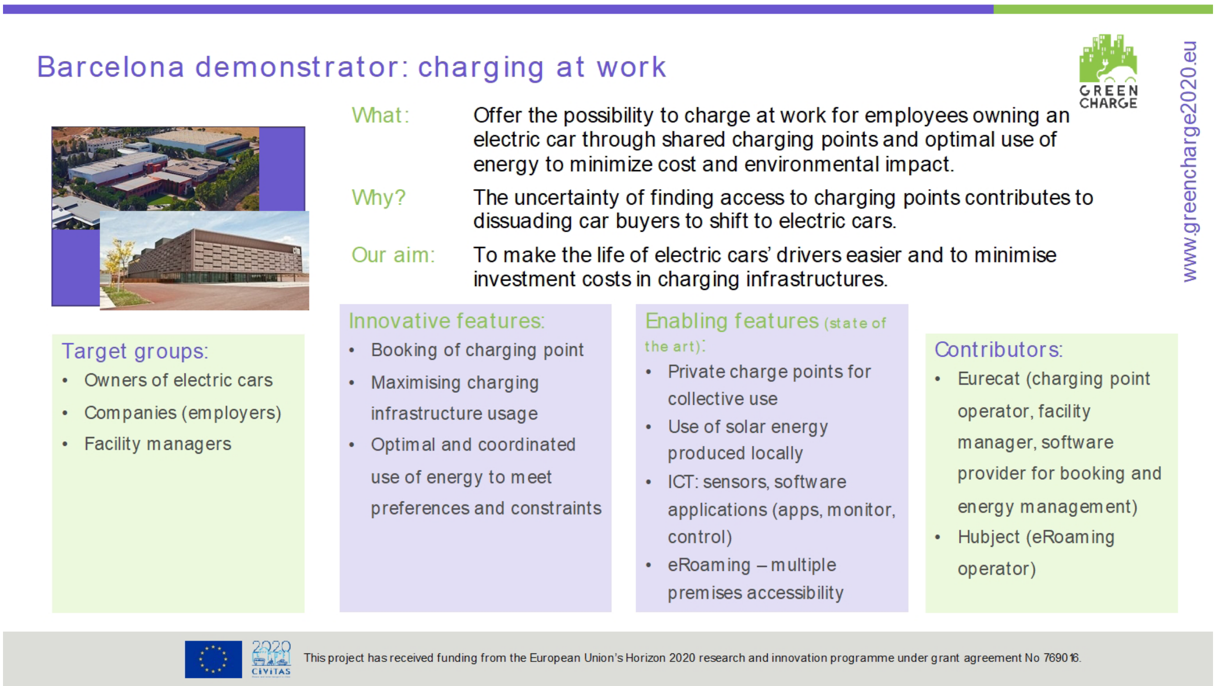


Figure 5-7 Barcelona demonstrator: green e-bike sharing service (Barcelona D3)

Demonstrated measures: GreenCharge demonstrates several innovative features, or measures as they are called in the in the evaluation of the demonstrators. The measures belong to four Measure Groups:

- EV fleet management, allowing the sharing of vehicles in different contexts.
- Charging management, allowing flexible charging and sharing of charge points.
- Smart energy management, enabling optimal use of energy.
- Business aspects, providing motivation for desired behaviours of stakeholders.

The measures may influence or depend on each other in various ways. For example, an optimal use of energy may encourage flexibility in charging, and fleet management requires the availability of charging and rewards eco-driving.

Table 5-1: Overview of measures and what is demonstrated for each demonstrator (part 1)

Some measures marked with (1) are not innovative themselves but serve as a necessary context to implement the innovative measures (source: D5.5)

Measure group	Measure (1) – SotA (2) – innovative	Description	Demonstrators						
			Oslo		Bremen		Barcelona		
			D1	D2	D1	D2	D1	D2	D3
EV fleets	Shared EVs (1)	A fleet of EVs shared among several users.				D	D		D
	Shared EVs integrated with public transport (2)	A fleet of shared EVs is integrated with public transport.							D
	Shared EVs in new housing cooperative (2)	A fleet of shared EVs is available to residents in a new housing cooperative to reduce the need for parking spaces/garage				D			
Charging	Private CPs (1)	The CP is owned and used by the CP owner or someone approved by the owner.	D		D	D			D
	Public CPs (1)	The CP can be used by the public.		D					
	Shared CPs (1)	The CP is shared with others when not needed by the CP owner.		D				D	
	Roaming (1)	EV users with a contract with one Electric Mobility Provider (EMP) can use the services of other EMPs/Charge Point Operators (CPOs).		D				D	
	Booked charging (2)	A time slot for use of a CP is booked in advance. Planned arrival and departure time and initial and target SoC are provided at booking time.		D				D	
	Battery swapping and charging (1)	Depleted EV batteries are swapped with fully charged ones.					D		
	Flexible charging (2)	Charging is done at any time within a given time window as long as the requested amount of energy is provided.	D		D		D	D	D
	Priority charging (2)	If there is not enough energy available to satisfy all charging sessions, priority sessions will be satisfied at the expense of non-priority ones.	D		D				
	Priority access to CP (1)	EV users has a prioritised access to CPs.						D	

continue next page...

Table 5-1: Overview of measures and what is demonstrated for each demonstrator (part 2)

Some measures marked with (1) are not innovative themselves but serve as a necessary context to implement the innovative measures (source: D5.5)

Measure group	Measure (1) – SotA (2) – innovative	Description	Demonstrators						
			Oslo		Bremen		Barcelona		
			D1	D2	D1	D2	D1	D2	D3
Smart energy management	Local RES (1)	Local renewable energy sources (RES), e.g. solar panels are exploited	D		D		D	D	D
	Local storage (1)	Energy is stored locally in stationary batteries for later use when it is advantageous.	D		D				D
	V2G (2)	Ability to exploit discharging of EVs connected for charging when possible within constraints set by user and beneficial for optimal demand profile of the building or neighbourhood.[7]	✪		✪			✪	
	Optimal and coordinated use of energy (2)	Energy demands (charging included) are coordinated with energy availability to reduce peaks and expenses. EV users' needs and other needs are considered.	D		D			D	D
Business aspects	Rewarding Eco driving (2)	The customers using shared EVs are rewarded if they accomplish Eco driving				D	D		
	Payment for sharing EVs (1)	Citizens pay for eMobility services.				D	D		✪
	Penalising priority in ESN (2)	EV users requesting priority are penalised or not rewarded	D						
	Rewarding flexibility in ESN (2)	EV users offering flexibility are rewarded. This may also include those allowing V2G.	D						
	Payment for shared CPs (2)	CP owners are compensated for offering their CPs to others.		D					
	Penalising blocking of CP (2)	EV users not using their booked time slot (no show or very late arrival), or are connected too long (blocking) are penalised.		D				D	
	Rewarding prosumers (2)	ESN benefits from being a prosumer by means of a positive Feed-in tariff or self-consumption.	D						
	Rewarding desired consumption pattern (2)	Energy tariffs may reward lower peaks or use of energy outside peak hours. The use of energy is adapted to reduce the energy costs.	D				D		

7 V2G requires EVs and CPs supporting discharging and an energy management system able to exploit it. None of the demonstrators include EVs and CPs supporting V2G, so the potential impact can only be investigated in simulations.

Table 5-2: Technology prototypes and systems implemented in the demonstrators

Demonstrator	System (component)	Partner	Functionality	TRL
Oslo D1: Charging in an Energy Smart Neighbourhood	Connected prosumer platform	eSmart	ESN energy management (aggregated level & all type of loads)	9
	ZET individual charge planning	ZET	ESN energy management (EV level)	7
	ZET.Charge App[8] & charge management tool	ZET	User interface and backend for charge planning and management	7
	Fortum Charge & Drive management	Fortum	Charge management	9
Oslo D2: Book a charger before your visit!	ZET.Charge App[9] & charge management tool & booking calendar	ZET	User interface and backend for charge management (advance booking included)	7
	Fortum Charge & Drive management	Fortum	Charge management	9
	eRoaming management system	Hubject	Roaming management	9
Bremen D1: GreenCharge@work	PMC WebApp & gridctrl (aggregator & ENCORE)	PMC	User interface and backend for charge management	7
Bremen D2: eCar sharing	ZET.share App[10] & fleet management & EV in-vehicle system	ZET	Fleet management, vehicle data collection	9
Barcelona D1: shared electric scooter with battery swapping	eScooter sharing service system & App[11]	MOTIT	User interface for vehicle reservation, IoT vehicle data collection, fleet management	8
	SEM scheduler & SEM forecaster	Eurecat	ESN energy management	7
	Eurecat charge management	Eurecat	Charge management	7
Barcelona D2: charging at work	SEM scheduler & SEM forecaster	Eurecat	ESN energy management	7
	Eurecat charge management	Eurecat	Charge management	7
	Eurecat App[12] & Booking system	Eurecat	User interface and backend for booking	7
	ZET.Charge App & charge management tool & booking calendar	ZET	User interface and backend for charge management demonstrating roaming	7
	eRoaming management system	Hubject	Roaming management	9
Barcelona D3: green e-Bike sharing service	SEM scheduler & SEM forecaster	Eurecat	ESN energy management	7
	Eurecat charge management	Eurecat	Charge management	7
	Atlantis Fleet Ap[13] & fleet management platform[14]	Atlantis	User interface for reservation, fleet management	7

8 The App is available on AppStore and Playstore: https://apps.apple.com/us/app/zet-charge/id1533967472, https://play.google.com/store/apps/details?id=com.zetcharge

9 The App is available on AppStore and Playstore: https://apps.apple.com/us/app/zet-charge/id1533967472, https://play.google.com/store/apps/details?id=com.zetcharge

10 The App is available on AppStore and Playstore: https://play.google.com/store/apps/details?id=com.zetshare, https://apps.apple.com/us/app/zet-share/id1497321575

11 The App is available on AppStore and Playstore: https://itunes.apple.com/es/app/ioscoot/id1256031117?mt=8, https://play.google.com/store/apps/details?id=com.ioscoot.app&hl=es

12 The Web App is available: greencharge.eurecatprojects.com

13 The App is available on AppStore and Playstore: https://play.google.com/store/apps/details?id=com.atlantis.emobility, https://apps.apple.com/es/app/atlantis-emobility/id1498934785

14 The App and URL for fleet management platform for administrator: https://play.google.com/store/apps/details?id=com.atlantis.technology.atlantisGPF, and www.atlantisfleet.com

Lessons learnt:
The development and deployment of demonstrators required the integration of systems from different sectors. The work has been challenging due to the lack of standardised interfaces, what fosters the need for a Reference Architecture as presented in section 3. In particular, a Neighbourhood Energy Management system (NEM) as demonstrated in Oslo is extremely complex as it involves a plethora of stakeholders from different domains (i.e., transport, energy, building). The installed technologies were, to a large extent, commercially off-the-shelf products, when treated on their own, but their integration has been time consuming due to missing, non-open, or under-documented APIs and has required tight cooperation with companies not participating to the project. Further, creating a realistic test environment for integration testing is not doable, and thus several errors could only be discovered through on-site testing. Therefore, we recommend building owners aiming at deploying a smart charging infrastructure to engage a system integrator with adequate technical expertise. Cities promoting building owners to acquire a smart and green charge infrastructure, should develop guidelines helping residences in choosing the right solutions.

In Bremen, car sharing is a crucial supplement to public transport options (tram, bus). For residents, car sharing is definitely an alternative to owning a private car. This behaviour mirrors with reducing the parking pressure in the city centre. As the amount of EVs is expected to increase dramatically in the coming years, additional charge options will also have to be offered. Therefore, integrating car sharing in new housing development is a direct incentive for residents to make use of this mobility option instead of using a private car. It would reduce the parking-pressure in urban areas, foster the reduction of private cars in city flats, and still keeping convenience for the residents with respect to their mobility needs high.

The legal regulation of the energy market in general, but in particular of the electricity market, is very complex and requires coordination of numerous stakeholders, if a specific charging infrastructure needs to be invested and operated. Ready-made systems comprising hardware and software solutions are advantageous in terms of costs and after-sale business. The backend solution integrating the demand- and supply-side for "green" charging will continue to play a key role in charging infrastructure during and after the foreseen ramp-up phase of EV market.

Used EV batteries will come into market with large numbers during this decade, when mass-produced EVs will be decommissioned. By then stationary energy storages adapted to company parking lots or to public mobility hubs will be available. It is still unclear who will dominate this market – start-ups or the OEM's themselves. In any case, in combination with on-roof PV power supply, this option will allow the commuting employees to recharge their private EVs together with the company's fleet-EVs – cost-efficiently, conveniently, and "green".


Unsplash / Kumpan Electric

Innovation context:
Many examples of electric vehicle charging innovation have come to light in the course of the Innovation Management task during the project; this includes other research and innovation projects and initiatives operating across Europe[15], and private sector initiatives. Some examples are given below, and whilst GreenCharge's unique selling point is its attention to local renewable energy integration (also demonstrated by other projects[16]), advances have occurred across the spectrum of charging solutions:

- Increased mainstreaming of electric propulsion technology for public buses, including opportunity charging technologies (e.g., ASSURED);
- Trials of induction technologies for rapid, short stay charging, e.g., taxis;
- New forms of vehicle management for L-category electric vehicles, e.g., swapping batteries, rather than transportation of whole vehicles for recharging (e.g. development of more robust and battery-swappable Lime scooter concepts over vehicle generations);
- Roll-out of renewable energy-supported charging stations at scale;
- Implementation of private/domestic/household charging solutions, with increased number of different providers offering expert advice and installation of different technological solutions (e.g. wall boxes), including more limited examples of joint solutions offering renewable energy such as solar rooftops and battery storage - but notably often focussing on individual household solutions rather than wider neighbourhood scale energy management, and without standardisation particularly regarding information and data exchange making holistic smart charging management ever more complex;
- Different on-street charging stations, from large installations obstructing pedestrian space to below ground solutions.

Despite these examples and developments, it is not felt that the "GreenCharge concept" has been fully embraced or demonstrated outside of the project in the mainstream. It therefore remains the challenge to convince charging suppliers of the advantages of remaining flexible to allowing and enabling energy management, as for users to be persuaded of the advantages and to be readily able to implement their own renewable energy generation or storage solutions. There is much knowledge from other projects that also remains to be exploited.

Some examples relevant to GreenCharge from the wider innovation space are provided to the reader for further research and examination relevant to their needs. These also provide potential partnerships and examples of settings for GreenCharge's results to be exploited within. These also demonstrate that the private sector[17], as well as individual users[18], are seeking solutions for their mobility and energy needs in this space – something will only increase in the future with the envisaged transition to electric vehicles of all kinds. Several aggregators or multipliers of knowledge are also in operation across Europe primarily aimed at industry and governments involved in the e-mobility transition.[19]

15 e.g. ASSURED, BSR Electric, CityxChange, eCharge4Drivers, eHubs, Elaad, "Electric Mobility Europe" projects (such as Electric Travelling and EVRoaming4U, Electrific, Elviten, e-Mob, eMobicity, EMopoli, Neon, Sharing Cities, EnerNETMob, "Smart Cities" projects (such as Grow Smarter), Solutions Plus, USER CHI

16 Other projects with identified joint mobility and renewable energy components include CleanMobilEnergy, Efficience, EV Energy, INVADE, MySmartLife, Ready, SEEV4CITY, SIMPLA, SmartenCity, Smarter Together, Stardust, Zenmo

17 Further examples of companies and initiatives identified as also being particularly active in the innovative space offering services and solutions in this area include ABB, Allego, Bosch, Enel X, FlexPower, GreenMotion, Has to be Mobility, Mer, MyEnergi, PowerFlex, PowerSwap, SIEMENS, Solar Edge, The Mobility House, Virta, Wenea, Zoov

18 e.g. as evidenced by online discussions (e.g. YouTube diaries such as Mortons on the Move and Andrew Till / Mr. EV) and consumer-focussed coverage (such as the Fully Charged Show, with approaching 1M YouTube subscribers) as well as home videos and online for a discussing, comparing and explaining solar e-mobility set-ups and a number of podcast series.

19 Relevant partnerships and initiatives include 2 Zero Emission (formerly EGVI), AVERE, Charge Up Europe, EIT Urban Mobility, Electrification Alliance, Eurelectric (including Evision), European Emobility Expertise Centre, EV100, EV Energy Taskforce, Platform for Electromobility, SCALE, Smarten, Solar Power Europe, TUMIVolt, UEMI, Zemo, ZEV Alliance (including Evision)

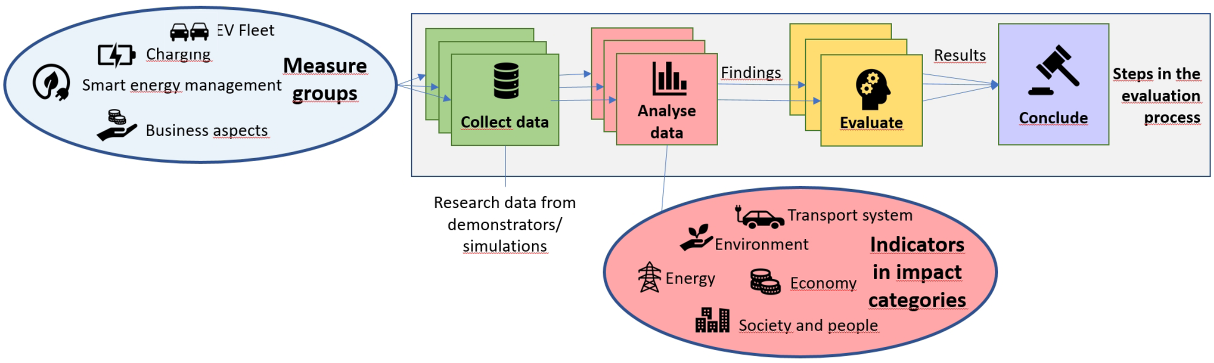
Examples of innovations complementary to GreenCharge	**Links**
Cars	
Forecourt-based car charging with renewable energy	www.gridserve.com/2020/03/10/uk-s-first-electric-forecourt-is-under-construction-opening-summer-2020 (Gridserve, UK) https://fastnedcharging.com/en/about-us (FastNed), Netherlands)
Solar canopies on car parking	www.iclei-europe.org/news/?c=search&uid=g78o2u7P (Glasgow, Scotland) www.aviva.com/newsroom/news-releases/2020/11/aviva-opens-one-of-the-uks-largest-solar-initiatives (Perth, Scotland) https://sustainablecities.eu/transformative-actions-database/?c=search&action_id=5ic0min5 (Barcelona, Spain) www.solarpowereurope.org/solar-in-the-driving-seat-solar-mobility-report (for further examples)
Charging integration within domestic rooftop solar, including Tesla solar glass example	www.youtube.com/watch?v=uI7wxNtrorQ www.tesla.com/solarroof
Solar powered e-car sharing	www.wedrivesolar.nl
Light electric vehicles	
Application of solar to cycle paths in the Netherlands	https://invest.utrechtregion.com/en/discover/news/the-worlds-longest-solar-panel-cycle-path-opens-in-utrecht-region
Solar charging for ebikes	www.youtube.com/watch?v=bFLUmXdb19Q http://solarpoweredbikes.tudelft.nl) (Delft, Netherlands) www.cities-multimodal.eu/news/energiraffen-karlskrona (Sweden) https://mobile.twitter.com/reggietricker/status/1327708072199020544 (Germany) https://mobile.twitter.com/reggietricker/status/1446864497377939457 (Germany)
Public transport	
Application of solar to metro station roof in Austria	www.interreg-central.eu/Content.Node/First-full-year-results-of-the-Vienna-PV-system.html

More information:

- D2.8/D2.15/D2.21 Final Report for Oslo/Bremen/Barcelona Pilot: Lessons Learned and Guidelines.
- D3.4 Final Business Model Designs.
- D4.5 Final Version of Integrated Prototype.
- D5.5/D6.4 Final Result for Innovation Effects Evaluation/Stakeholder Acceptance Evaluation and Recommendations.
- Shanshan Jiang, Marit Natvig, Svein Hallsteinsen and Karen Byskov Lindberg. *Lessons Learned from Demonstrating Smart and Green Charging in an Urban Living Lab*. AINA 2022.

6 Evaluations and simulations

Figure 6-1 Overview of the evaluation approach for the impact evaluation



The aim of the evaluation and simulation activities was to establish knowledge about the implementation and impact of the GreenCharge solutions, and to ensure that the knowledge is established in a scientifically correct way. Thus, both the evaluation approach and the evaluation results are emphasized as important achievements.

Target users:
The GreenCharge results on evaluation and simulation are relevant to all interested in the impact of green and smart charging and the lessons learned from the implementation process of such solutions. This also includes scientists and others that may re-use the approach and the indicator framework used in the impact evaluation (such as local authorities seeking indicators to measure their own electric mobility interventions).

Highlights:
The measures in Table 5-1 define what is implemented in the demonstrators and included in simulation scenarios. The measures are the target to be evaluated, and they are grouped into the measure groups illustrated in Figure 6-1. A process evaluation addresses the implementation process, and an impact evaluation the effects of the measures.

An indicator framework has been defined to support the impact evaluation. The impact categories from the CIVITAS Evaluation Framework [1] were used alongside these indicators when this was feasible. Some new indicators were however needed, and existing indicators also were adapted to cover these needs. The new and the adapted indicators for the different impact categories are:

Society-people:
- Adapted indicators: Acceptance, Awareness, Operational barriers, Perception level of physical accessibility of service
- New indicators: Shared EVs per capita

Transport System:
- New indicators: Number of EVs, Number of charge points, Utilization of charge points, Charging availability, Charging Flexibility

Energy:
- New indicators: Share of battery capacity for V2G, Share of green energy, Peak to average ratio, Self-consumption

Environment:
- Adapted indicators: CO_2 Emissions

Economy:
- Adapted indicators: Average operating cost, Average operating revenue

The demonstrators are novel, but still limited in a project of the scale of GreenCharge with respect to size and complexity. Thus, the CIVITAS approach for the real-life demonstrators are complemented by simulations. This hybrid approach has allowed an investigation of scale-ups and varying factors. The simulation scenarios simulated are for more full-fledged energy smart neighbourhoods and allow for more learning.

The data collected from the demonstrators are both qualitative and quantitative. The data collection methods used are interviews, surveys, focus groups and automated data collection from software systems. The data collected automatically is used in the calculation of quantitative indicators. Several software tools have supported the evaluations:

- **KPI calculator** supporting the calculation of the quantitative indicators. Data from both demonstrators are used as input.
- **Discrete event simulator** simulating scenarios in an energy smart neighbourhood (ESN). Devices like PV panels, stationary batteries, charge points, etc. are defined, and events producing, storing, and using energy are simulated according to defined rules. Relevant KPIs are calculated.
- **Optimiser** integrated with the simulator to support the simulation of the optimal energy management. Several approaches can be used with respect to optimisation (soonest[20], lowest costs, and greenest energy).

Lessons learnt:
The process evaluations addressed the implementation of the measures listed in Table 5-1. The main result is that involving all affected stakeholders is important in order to achieve a behavioural change and an acceptance of smart charging. New business models with a broader scope than traditional business models are also needed. The value is not just linked to money but also to a desired behaviour. EV Users must be rewarded for showing flexibility with respect to when the charging can be carried out since such flexibility arrange for smart energy management and better utilisation of green energy. It was also experienced that realisation of smart charging in an energy smart neighbourhood (ESN) is challenging due to immature technology and lack of standards. An integration of systems from different providers and hardware not originally designed for ESNs require careful investigations, planning, and customisation. Legacy systems are not always prepared for the required integrations and control, and interfaces and solutions must be customised to the actual ESN. The access to SoC directly from the vehicle batteries is a currently a problem as this is not supported by most protocols and EVs. It was also experienced problems with the use of 2nd life EV batteries as stationary batteries. As it is today, there are no formalities that ensure the quality of such batteries.

Within the Society and People impact category the results are varying. The demonstrators addressing charging at work (Bremen D1, Barcelona D2) or travelling to work (Barcelona D3) are highly affected by the COVID situation. It has been difficult to impact the awareness and acceptance when people are working at home. The charging for residents in Oslo does however have a high degree of acceptance and awareness. The results for EV sharing also varies. The EV sharing in Bremen D2 have struggled to get users. Two challenges that may be typical to Germany: People are reluctant to use car sharing services (they prefer to use their own car), and they are reluctant to use electric cars. In addition, the COVID situation has also caused scepticism to the car sharing. The customers that have used the service are however very satisfied, and they have used it several times. The B2B eScooter sharing in Barcelona has been operational with many customers. In this case, the COVID situation has had a positive effect on acceptance and awareness since the scooters were used in food deliveries.

For the Transport system impact category, the impact evaluation shows that almost 80 charge points have been established during the project period and that more than 5000 charge sessions have been carried out. For charging at work and at private charge points, the EVs are connected for longer periods than is required for charging. Thus, the inherent flexibility is high.

20 No optimization – to establish a baseline.

For the Energy impact category, simulations are used to study the effects of the individual measures. Charging flexibility in combination with smart energy management and stationary batteries contributes to a reduction of energy peaks and a higher degree of self-consumption (of the energy produced by the PV panels). Snow has for example covered the PV panels in December and January. Simulations show that the effect of stationary batteries to some extent can be overtaken by smart energy management. Thus, energy optimizers software can partly replace the much more expensive stationary batteries.

Within the environmental category, the focus is on CO_2 emissions. The table below provides an overview of the results.

Table 6-1: Evaluation results for environmental impact

Demonstrator	With energy from grid	With the PV panels and no smart energy management	With PV panels and smart energy management
Oslo D1	31.38 gCO_2eq/kWh	30.14 gCO_2eq/kWh[21]	22.27 gCO_2eq/kW[22]
Bremen D2	Savings: > 3500 kg CO_2		
Bremen D1	189 gCO_2eq/kWh	58.7 gCO_2eq/kWh[23]	45.9 gCO_2eq/kWh[24]
Barcelona D2	138 gCO_2eq/kWh	137.51 gCO_2eq/kWh	137.51 gCO_2eq/kWh[25]

For the Economy impact category, the business models are studied. For Oslo D1, the charging service contributes to the revenue, but so does also the integration of charging with smart energy management. The PV panel has decreased the energy costs by 10%, but the potential is higher. A stationary battery will increase the self-consumption from 50 % to about 100 %. This will reduce the peak level costs, especially when more EVs are charged. The main reduction of the peak costs will however come from the smart energy management. For Bremen D2, the revenue has been low due to the low acceptance of the service, as described above, and in Barcelona D1 the business model seems to be sustainable.

21 This number is for period from August 2021 to January 2022.

22 This number is for one week in August 2021.

23 This number is for location 3 from September to December 2021.

24 This number is for Location 3 from one week in September 2021.

25 The number is the same for with or without smart energy management as all the PV production has been self-consumed.

Innovation context:
Alongside the CIVITAS indicators, over the course of the project the SUMI indicators have been published by the European Commission. These cover a number of specifications for the measurement of transport-related indicators, including CO_2 emissions, and can be found in the CIVITAS tool library.[26]

Further challenges also arise in the measurement of the modal split of electric vehicles, compared to internal combustion vehicles, as this is less straightforward even for newer forms of modal split measurement (such as mobile phone tracking of users, and conversion of this data to an assumed mode of travel). The identification and assignment of emissions from electric vehicles will also provide a challenge to carbon accounting in the future, with the "scope" of emissions potentially varying according to whether electric vehicles are charged domestically, in the workplace, or at "public" facilities where electric consumption can be more easily distinguished between other forms of electricity usage. This is currently a challenge and discussion within the carbon accounting industry, which has previously been used to more centralised sources of fuel provision (e.g., at service stations and depot facilities).

More information:

- D5.3 Simulation and visualisation tools
- D5.5/D6.4 Final results for innovation effects evaluation/Stakeholder acceptance evaluation and recommendation (combined deliverable)
- D5.6 Open research data (date are published as open research data in the European open research data repository Zenodo (https://zenodo.org)
- Marit Natvig, Shanshan Jiang, Svein Hallsteinsen, Salvatore Venticinque and Regina Enrich Sard. *Evaluation Approach for Smart Charging Ecosystem - with Focus on Automated Data Collection and Indicator Calculations*. AINA (3) 2021: 653-666.
- Salvatore Venticinque, Beniamino Di Martino, Rocco Aversa, Marit K. Natvig, Shanshan Jiang, Regina Enrich Sard: *Evaluation of innovative solutions for e-mobility*. Int. J. Grid Util. Comput. 12(2): 159-172 (2021).
- Dario Branco, Beniamino Di Martino and Salvatore Venticinque. *A Big Data Analysis and Visualization Pipeline for Green and Sustainable Mobility*. AINA (3) 2021: 701-710
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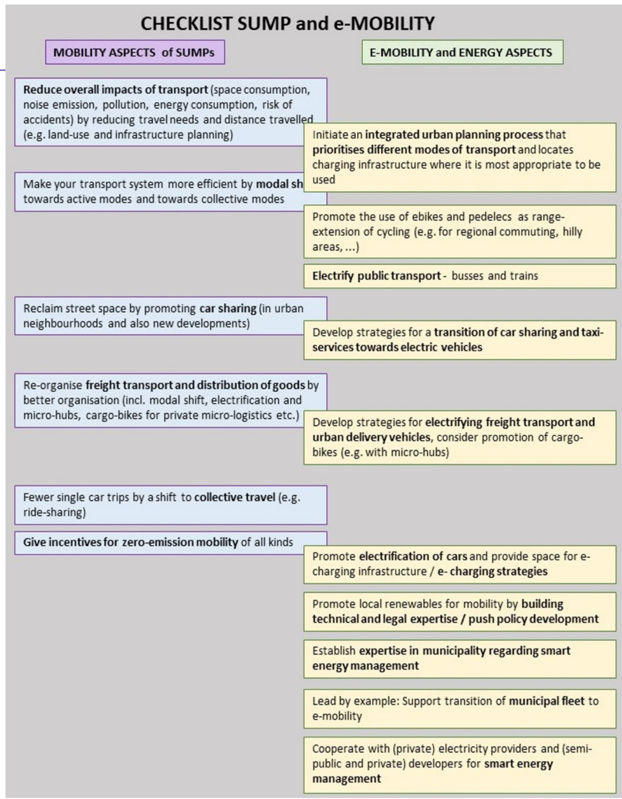
- Rocco Aversa, Dario Branco, Beniamino Di Martino and Salvatore Venticinque. GreenCharge Simulation Tool. In the proc. of WAINA 2020: 1343-1351.
- Rocco Aversa, Beniamino Di Martino, Salvatore Venticinque, Marit Natvig, Shanshan Jiang and Regina Enrich Sard. *Evaluating Technology Innovation for E-Mobility*. In the proc. of WETICE, 2019.

26 https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/sumi_en

7 SUMP and policy recommendations

Figure 7-1 The Sustainable Urban Mobility Planning (SUMP) process as it provides the context for electric mobility planning (source: D7.2)

Sustainable Urban Mobility Plans (or SUMPs) are a framework which provides for the logical creation of a strategy document that assesses transport (or mobility) needs, involves stakeholders at all stages of discussions, and sets out solutions which support visions of the future and their measurable targets. Whilst SUMPs provide a strategic viewpoint and set a basis for finding and funding solutions, they less regularly articulate individual specific measures or solutions, which are usually contained in sector-specific action plans (such as one on eMobility) or individual project proposals. A variety of different approaches have been found in GreenCharge's Uptake Cities (as reported in Deliverable 7.3). The attention to and acceptance of electric mobility as part of sustainable urban mobility planning, particularly for car-based electric mobility, is still nascent and fluid in



many cities, which retain a focus on traditional challenges involving walking, cycling and public transport. The overall picture of electric mobility in cities was debated at many sessions during GreenCharge's final Informed Cities event, including *Repurposing mobility: The cases of Barcelona, Bremen, Freiburg and Oslo*.[27] GreenCharge has worked with its pilot cities and Uptake Cities to develop its recommendations for eMobility in SUMP, in the context of EU guidance emerging in this area over the course of the project.

Target users:
The target users for the development of Sustainable Urban Mobility Plans are local authorities. SUMP is usually carried out at a local level, by a single local authority across a coherent urban area, by individual local authorities within a subdivided urban area, or across a broader metropolitan or regional level. Many, but by no means all, cities have a SUMP, or a local variation such as a transport plan or ordnance, dependent on both country and level of advancement in transport planning. For those who do not, highlighting to local politicians of the opportunities is an additional target audience alongside the local officers themselves.

SUMPs are also of interest to campaigners for increased sustainable travel investment, as they seek to understand the local authorities' balance of interests and commitments, in order to hold politicians to their visions (or indeed, influence a change in their priorities). SUMPs are less well recognised by the private sector, where transport operators often develop their own business plans, objectives and targets without meaningful reference to or integration with public sector plans such as SUMPs. However, for the vision of GreenCharge to come about, the private sector as well as related sectors such as the energy sector must be recognised and have a stake in SUMPs, which should mutually reflect the concerns of these sectors.

Highlights:
The development of SUMP approaches is demonstrated in two key outputs: *a policy brochure (D7.1)*, guiding the overall considerations, at the start of the project; and a *best practice guidebook (D7.2)*, further guiding considerations at a measure level, towards the end of the project. Both retain relevance and have been designed with a public audience and readership in mind. SUMP has been discussed with Uptake Cities in the project and their respective priorities and interests understood. The documents have also been influenced by the pilot cities of GreenCharge, notably the City of Bremen as the winner of the CIVITAS Transformation Award during the course of the project in 2019 and main author of the documents. It was beneficial that GreenCharge was able to exchange experiences with the Uptake Cities through a study visit to Bremen and through several online events and exchange with the city's officers over the course of the project. The Business Models workstream also provides recommendations for cities structuring multi-stakeholder investment in e-mobility (Deliverable 8.5).

Unresolved discussions on the role of electric mobility in the wider context were able to be discussed amongst participants in the Informed Cities Forum[28] held towards the end of the GreenCharge project.


Unsplash / Markus Spiske

27 www.youtube.com/watch?v=0JD63AZfPSg&list=PLv-mhCFis0sXBFXpU1UpELWBgx3KfnulU&index=5

28 www.youtube.com/playlist?list=PLv-mhCFis0sXBFXpU1UpELWBgx3KfnulU

Innovation context:
GreenCharge has become aware and has sought to engage in various policy processes affecting SUMP during the course of the project. This has including contributing to reviews and consultations on the SUMP topic guide on electrification, facilitating a session on electric mobility at the Smart Cities Marketplace, and through ICLEI submitting contributions to the *Consultation on the Review of Directive 2018 /2001/EU on the promotion of the use of energy from renewable sources, Consultation on the revision of the Energy Performance of Buildings Directive 2010/31/EU and the Consultation on the revision of the Alternative Fuels Directive 2014/94/EU*. Such directives and guidance have the potential for significant implications as to how energy and transport interrelate going forward. The City of Bremen has paid particular attention to policy processes in Germany, and how federal, state and local initiatives interrelate on the theme of electric mobility, and has helped conveyed these to Uptake Cities through webinars. Stakeholders from outside the project were also brought together from outside the project to discuss the role of eMobility in the GreenCharge final Informed Cities Forum, for example in the session *The future of mobility: Which electric vehicle fairy tale will you fall in love with? - The Bachelor*, recognising the ongoing debates and sometimes conflicting views and beliefs about the role and importance of electric mobility.[29]

Through the Innovation Management task, learning from a number of other related projects and initiatives has been identified placing GreenCharge in its wider context, and passed on both within the consortium and to Uptake Cities for their own learning, such as:

- Relevant project conferences (e.g. EU Cities and Regions Week, proEME, BSR Electric, SEEV4City, Smart Cities Marketplace)
- Other online materials, particularly video-based content (e.g. from Clean Mobil Energy, Cities Shift, ECCENTRIC, EIT Urban Mobility, Energy Savings Trust, EV Café, EV Energy (including webinar), EV Energy Taskforce, EV Forums, Interreg (and 2021 series), Low Carbon Hub, My Smart Life (on energy and mobility), Sharing Cities, Solutions Plus,
- E-mobility content at significant other events and conferences (e.g. Autonomy, AVERE, CIVITAS Forum, EU Sustainable Energy Week, EU Urban Mobility Day, European Mobility Week, EV Summit, EV World Congress, Global Emobility Forum, FIA Smart Cities Forum, GreenTech Festival, MOVE, Revolution, Spark)

Key supporting documents have also been identified which support GreenCharge's own publications, such as:

- Electric Mobility Europe (EMEurope) D6.4 - Best practice catalogue for policy makers (No. 1 and No. 2)
- CIVITAS guidance, e.g.
    - CIVITAS INSIGHT E-mobility: Make it happen through SUMPs!
    - CIVITAS INSIGHT E-mobility: From strategy to legislation
    - CIVITAS policy brief: Clean fuels and vehicles
    - Electric Vehicles and the Grid
    - Recommendations for public authorities for procuring, awarding concessions, licences and/or granting support for electric recharging infrastructure for passenger cars and vans

Further linkages to related projects and programmes are also included in Deliverable 7.2.

29 www.youtube.com/watch?v=4Qeb44CyH1M&list=PLv-mhCFisOsXBFXpU1UpELWBgx3KfnuIU&index=8

Lessons learnt:

These processes of the development of the SUMP guidance in GreenCharge have highlighted SUMP to those in the project who do not work at the policy level and may have been unfamiliar with mobility planning before.

In overall terms, eMobility has not been on the top priority list in the current urban mobility planning in cities. It is important to put it into context and understand the overall goals and ambitions that cities seek to achieve. This includes reducing car ownership and use, which is a challenging narrative for technology providers and a marketplace audience with a desire to maximise numbers of units sold (e.g., electric cars, charge points, etc.). Acceptance within the project of the need for shared vehicle ownership approaches has been good, with the opportunities this creates for different types of software to support SUMP aims appreciated. However, for many external events where electric mobility is promoted, the spectre of reducing car ownership and use is the elephant in the room.

The main indicator of success may be the number of charge points on the streets, rather than operational outputs such as the reduction on CO_2 or the avoidance of significant increases in peak energy demand.

It is also clear that there are limited examples of good practice which can demonstrate the whole Reference Architecture of GreenCharge, and therefore the ability of local authorities to get inspired about its importance is reduced. In transport terms, issues such as smart energy management is not seen as essential or integral to the function of the mobility system for its users – but are essential to the wider energy context and sustainability in terms of price and supply for energy for mobility in the longer term. Such integrated thinking remains a challenge to achieve (perhaps until such time as electricity crises also affect the transport system).

Further work:

There is a need for development of mutual understanding across energy, transport and the private sector. This need has been recognised (e.g., SIMPLA) and advanced (e.g., Smart Cities Marketplace, CIVITAS FastTrack) but mutual respect, collaboration and coherence has yet to be mainstreamed. Partner involvement in related projects will continue to develop this ambition.

It is recommended that an electric mobility-specific Coordination and Support Action could be of benefit in continuing to build on the knowledge of GreenCharge and other related projects, and further develop and exploit the learning so local authorities can debate and appreciate its importance in their policy roadmaps (referred to in Section 8 below) going forward.

More information:

- D7.1 GreenCharge SUMP eMobility Approach.
- D7.2 Recommendations and Guidelines for Integrating Electric Mobility into SUMPs.
- D8.5 Viable Business and Replication Plans

Pixabay / andreas160578

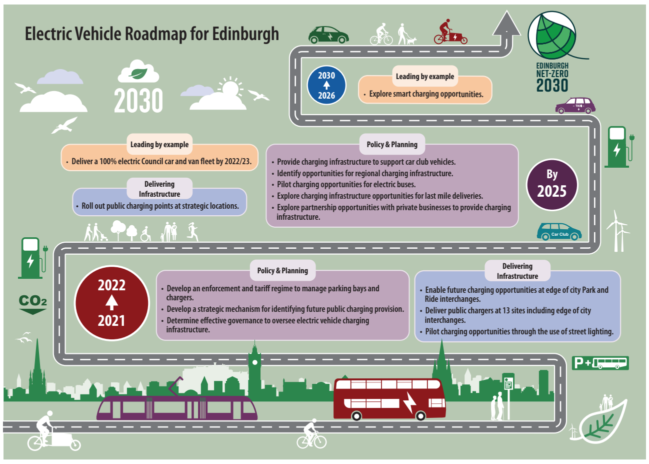
8 Uptake cities roadmap

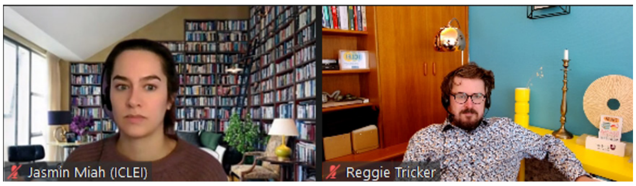
GreenCharge has completed a coaching programme with a group of Uptake Cities, who are not partners in the project but seek to learn from it (reported in Deliverable 7.3). This has been through a combination of a physical workshop and study visit, online 1:1 coaching and interviews, group webinars and remote study visits. This has brought the skills and knowledge of the consortium partners and pilot cities directly to Uptake Cities, allowing them to question the approaches in GreenCharge and for them to help set the overall direction and context for the project's work. In culmination, individual Uptake Cities produced a graphical "roadmap" tailored to their own specific needs, to set out the future for electric mobility in their own city.

Target users:
The target users were the specific Uptake Cities engaged in the project, including the colleagues and stakeholder representatives interacting with GreenCharge on a daily basis. It is intended that this is also useful to inspire other cities to appreciate the value of simple depictions of their intentions, and to use the opportunity to bring together previously unconnected threads of knowledge or different agendas over time and sectors.

Highlights:
The study reports for learning activities are written in an easily digestible form and record the knowledge and points of discussion exchanged. Likewise, the roadmaps are presented in a one-page graphic that is easy to understand in a single view. This has enabled GreenCharge to interact with local authorities outside of the project on a 1:1 basis, including for example facilitating a cross-departmental online workshop bringing voices together for the first time in the City of Edinburgh.

Figure 8-1 Example of Roadmaps Development and Reflection Process in Uptake Cities





Positive feedback was received from the Uptake Cities involved.

"The roadmap is really useful for us because in the next months we will update the actual mobility strategy... And we will use all the knowledge we got and experiences from the project."

"Thank you for helping the city improve e-mobility."

Lessons learnt:

The lessons learnt parallel with those reported under the SUMP achievements (see Section 7). The level of detail which local authorities themselves require or are interested in being familiar with has been a learning point during the project. The importance of local energy management or the details needed for the effective operation of software to manage this is of lesser day to day concern to transport planners than their traditional interests; it is therefore not delved into in great detail. eMobility charging can also be within the purview of procurement rather than mobility specialists, and in this case specifications may be generic or not catch all of the requirements necessary for smart energy management (such as interoperability, multimodality, and local data exchange).

Opportunities for site visits and exchanges have also been fewer than those planned at the start of the project, due to pandemic-related travel limitations, and so this has also affected local authorities' priorities, motivation, day to day availability and tangible chances for practical knowledge exchange.

Innovation context:

Many roadmaps were found to exist in the world of mobility, from process maps guiding the overall SUMP process[30], to strategic planning documents and initiatives. Organisations such as ERTRAC[31] and STRIA[32] employ their own roadmaps in the field of electrification, with some examples of local authorities also using these for their own strategies globally.[33] Previous research projects have also tackled this topic specifically.[34] These share a common interest in planning over time. Publications comparing other cities have also been of use in informing advice to cities and showcasing good practice, such as the EV City Casebook[35] from the IEA and Global EV Capitals[36] from the ICCT.

Further work:

Study tours to new proven technological systems would be of absolute benefit to local authorities, and it will be determined how this can be supported (e.g., through the CIVITAS programme). As members of networks, such as ICLEI, opportunities to maintain relations with pilot and Uptake Cities will be sought.

Further distillation of the advantages of considering technological capabilities of transport management systems to interact with smart energy management systems would also be of benefit. Deliverable D8.5 suggests ways local authorities can further develop their roadmaps to further emphasise and integrate green energy aspects.

More information:

- D7.3 Lessons Learned from Roadmap Development in Uptake Cities.
- D8.5 Viable Business and Replication Plans.

30 www.eltis.org/mobility-plans/sump-guidelines

31 www.ertrac.org/index.php?page=ertrac-roadmap

32 https://ec.europa.eu/info/research-and-innovation/research-area/transport/stria_en

33 e.g. Electric Vehicle Readiness Roadmap - City of Fort Collins (fcgov.com)

34 www.urban-transport-roadmaps.eu

35 www.iea.org/reports/ev-city-casebook-and-policy-guide-2021-edition

36 https://theicct.org/wp-content/uploads/2021/06/Global-EV-Capitals_White-Paper_06032017_vF.pdf

9 Conclusions and future work

The achievements presented in this deliverable can be summarised into the following result groups:

- *Business models*: The GreenCharge project has designed and tested business models for the demonstrators. In addition, two futuristic business models have been proposed.
- *Technology prototypes*: The demonstrators and the accompanied business models have been implemented by technology prototypes realising innovative features defined in the GreenCharge Reference Architecture.
- *Open specification*: This includes GreenCharge Reference Architecture specification and recommendations on interfaces and protocols that need standardisation.
- *Evaluation results and lessons learned*: These include Open Research Data collected from the demonstrators, tools for evaluation and simulation as well as lessons learned from the demonstrators and evaluation results.
- *Recommendation and deployment guidelines*: These include recommendations and guidelines for integrating eMobility into SUMPs and Uptake Cities roadmaps for city planners and policy makers.

The GreenCharge project has had a high level of innovation ambition. This has not been an easy road due to regulatory and practical constraints, as well as the COVID-19 impact. Some proposed innovative features, e.g., V2G and full-fledged ESNs, could not be demonstrated in real life in the project due to regulatory and practical constraints in the current state of the art. The evaluation of the demonstrators has also been impacted with lack of or fewer users and delays due to COVID 19. These problems were however to a large extent mitigated through simulations based on data collected from the demonstrators.

The challenge and the lessons learnt from the technology prototyping for the demonstrators reinforced the need for standardisation to facilitate the integration of systems and access to the data needed. There is also a need for future technology and business models supporting the Energy Smart Neighbourhood (ESN) concept. This requires the cooperation of homeowners/housing cooperatives, energy providers, local authorities, transport providers at a neighbourhood level.

Currently, eMobility is not the top priority in urban mobility planning in cities. There is a lack of awareness and priority of the integration of eMobility and the ESN concept in SUMPs. Examples of good practice that can demonstrate the whole GreenCharge Reference Architecture can inspire local authorities towards the awareness and acceptance of the smart and green charging in ESNs. Further development of mutual understanding and collaboration across energy, transport, private sectors and local authorities is needed for future smart and green charging and wide adoption of EVs.

Unsplash / Vincent Guth

10 Additional references

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Summary of Project Achievements

GreenCharge Project Deliverable: D1.4

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Oslo

Type of EV | Energy | Location

Bremen

Type of EV | Energy | Location

Barcelona

Type of EV | Energy | Location