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

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

greencharge2020.eu

GreenCharge Project Deliverable: D2.8

Final Report for Oslo pilot: Lessons Learned and Guidelines

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About GreenCharge

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

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

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

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

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

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

For more information

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Executive Summary

This deliverable describes the Oslo pilot of GreenCharge. The Oslo pilot comprises three demonstrators, OSL.D1, OSL.D2 and OSL.D3. All three demonstrators are associated with the Røverkollen housing cooperative. The Røverkollen housing cooperative comprises several building blocks, both apartments (246) and a parking garage.

The objectives of the Oslo pilot were 5-fold, understanding:

O1. How new **business models** with an intelligent billing system can take consumer acceptance and ownership into account

O2. How a **booking system** for charging services can be directed towards certain costumer groups

O3. How to facilitate for **cost-efficient home-charging** in housing associations with limited grid capacity

O4. How an **integrated smart charging solution** can balance charging of EVs with local energy use and electricity production

O5. How the **user interface** and services for EV charging will work in different situations and for different user groups.

OSL.D1 mainly addressed O1, O3, O4 and O5. OSL.D2 mainly addressed O1, O2 and O5. OSL.D3 did not directly target any of the objectives but was implemented to collect data regarding energy consumption in flats for simulation purposes.

A major success-factor in relation to the demonstration activities was to identify and mobilize an orchestrator that can leverage viable business models. For the Oslo pilot, this became Røverkollen housing cooperative.

The Oslo pilot contribute directly to three of the project's expected results:

- (R_ELL) **Evaluation results and Lessons Learned** - documenting the Oslo pilot provides learning from planning and implementation of different measures to support increased uptake of electric mobility
- (R_BM) **Business Models** - i.e., how the orchestrator connects all stakeholders in the ecosystem and exchanges information, energy, cost and revenues
- (R_TP) **Technology Prototypes** - comprising the developments needed to fulfil the five objectives listed, including the integration with legacy systems. New developments include
  - Neighbourhood energy management system (NEMS) provided by ESMART
  - Charge management system (CMS) provided by FORTUM
  - ZET.Charge app provided by ZET
  - Roaming provided by HUBJ

This deliverable summarizes the tasks related to integration and activation of the different subsystems to fulfil the objectives of the Oslo pilot, and outlines some of the challenges experienced. In addition to the technical measures, it also describes business measures and supporting activities that was needed to fulfil the objectives of the pilot. Supporting measures includes information to, and collecting feedback from users (information campaigns, surveys, interviews etc.)

During the project, 65 parking spaces were equipped with charging points, and four publicly available outdoor parking spots were equipped with bookable charging opportunities.

Based on the experience from implementing and operating the Oslo pilot both guidelines and recommendations for future work can be extracted. Major takeaways include:

- Define activities as research and innovation activities to keep commercial aspects at bay
- Integration of non-standardized components and interfaces needs close collaboration between all actors involved
- Ensure tight cooperation and an open dialogue with the problem owner (in this case the housing cooperative)

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List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
AI	Artificial Intelligence
BEV	Battery Electric Vehicle
CMS	Charge Management System
CP	Charging Point
CPO	Charging Point Operator
CPP	Critical Peak-Power
CS	Charging Station
DC	Direct Current
DOW	Description of Work
DR	Demand Response (see List of Definitions)
DSO	Distribution System Operator (related to electric power distribution)
EMP	Electric Mobility Provider
EV	Electric Vehicle
EVSE	E-vehicle supply equipment
ICT	Information and Communications Technology
KPI	Key Performance Indicators
LEM	Local Evaluation Manager
LRG	Local Reference Group (stakeholders)
ML	Measure Leader
NEMS	Neighbourhood Energy Management System
OCP	Optimal Capacity plan
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
OICP	Open InterCharge Protocol
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic
RES	Renewable Energy Source

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Abbreviation	Explanation
RFID	Radio Frequency Identification
SC	Site Coordinator
SoC	State of Charge
SUMP	Sustainable Urban Mobility Plan
V2G	Vehicle-to-Grid
WP	Work Package

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List of Definitions

Table 2: List of definitions

Definition	Explanation
CCS	Combined Charging System
CHAdeMO	Tradename for Protocol for Fast Charging in the range 6-200kW
Charge management system (CMS)	The Charge Management System balances the load between the connected chargers and keeps within the OCP (Optimal Capacity Plan) generated by NEMS.
Demand Response	Often abbreviated to "DR". Demand response means adjusting power consumption according to requests from the DSO.
DSO	Distribution System Operator – responsible for operating and maintaining the electricity distribution grid.
Energy Smart Neighbourhood (ESN)	An energy smart neighbourhood (ESN) is a group of buildings embedding local RES and local energy storage and using smart control equipment to adapt the energy demand to the local production so as to reduce the burden on the public grid and the power bill. The smart control equipment does this by predicting local energy demand and energy production from local RES and leveraging demand flexibility and local storage resources to shift the loads in a coordinated way within the neighbourhood. The aim is to minimize the amount of energy taken from the grid, the demand peaks and the energy bill. As these may be partially conflicting goals, the inhabitants of the neighbourhood must define policies defining how to balance these goals.
Measure	A measure is a mobility or charging related action implemented by a city or other stakeholders, e.g., the implementation of a new infrastructure, the provision of a new service, a new organisation of the travel to work, or activities to change awareness, acceptance or attitude and behaviour of citizens or visitors
Neighbourhood energy management system (NEMS)	An ICT system implementing the smartness of an energy smart neighbourhood.
Optimal capacity plan	The Optimal capacity plan is generated by NEMS and sent to CMS to perform load balancing between the connected chargers in the garage
Photovoltaic	Photovoltaic panels (solar cell panels) convert light into electricity using semiconducting materials
Radio Frequency Identification Tags (RFID)	An RFID tag is an electronic tag that exchanges data with an RFID reader through radio waves
Renewable Energy Source (RES)	Renewable Energy Source is a category of energy sources, which does not involve the burning of fossil fuels as part of the energy production process. The most popular RES are photovoltaic panels, windmills and hydroelectric power

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Definition	Explanation
	plants. Typically, the carbon footprint of RES (caused by the building, operation and maintenance of the production facilities) lies in the area of 10 – 50 g CO2 equivalents per kWh, while for fossil energy sources like natural gas, oil and coal the carbon footprint lies in the area of 500 – 800 g CO2 equivalents per kWh. Nuclear power is not commonly counted as a RES, since the energy production process does consume a fuel and does produce a problematic waste (radioactive material). However, its carbon footprint is in the lower end of the RES range
Scenario	A scenario describes a specific use of a proposed system by illustrating some interaction with the proposed system as viewed from the outside, e.g., by a user, using specific examples. In GreenCharge, a scenario is a higher level of description of the system and can be modelled using one or several use cases.
State of charge (SoC)	The state of charge (SoC) is an indication of the amount of energy stored in a battery. It is given as a percentage, meaning the percentage of the full capacity currently available in the battery. The SoC is difficult to measure accurately, but several methods are available to give an approximate value, and most EVs have an instrument on the dashboard showing the SoC.
SotA (State of the Art)	Measures which are commonly implemented and in operation, or there exists demonstrators.
SUMP (Sustainable Urban Mobility Plan)	A SUMP is a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles[1].
Use case	A use case describes how a system will be used and is a tool for modelling requirements of a system. In GreenCharge, a scenario is a higher level of description of the system and can be modelled using one or several use cases.
Type 2	Connectors admitting charging with 43 kW maximum from 3-phase AC (alternating current).
Vehicle to Grid (V2G)	Vehicle to Grid means to use the energy stored in the batteries of EVs connected for charging to provide energy to the grid in peak load situations.

[1] https://www.eltis.org/mobility-plans/11-what-sustainable-urban-mobility-plan

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1 About this Deliverable

1.1 Why would I want to read this deliverable?

This document describes the lessons learned from implementing the Oslo pilot in the GreenCharge project. The Oslo pilot is located at the Røverkollen housing cooperative and comprises several demos. This includes demonstration of charging solutions that balances charging of EVs with local electricity use and production and bookable outdoor chargers accessible by roaming agreements. To perform the demonstrations, it was necessary to integrate existing components (both software and hardware) with new software developments. This document contains lessons learned from installation, configuration and running the demonstrators, and concludes with guidelines and recommendations for replication of the demonstrated solutions to other contexts.

1.2 Intended readership/users

This document is mainly targeting parties that want to replicate some of the solutions and results in other, but similar contexts. This includes the Local Reference Group for Oslo, the wider Uptake Cities Group and potentially other innovators and organizations:

- Housing cooperatives
- City and district administrations
- Software developers for energy smart management
- Charging Point Operators (CPO)
- Electric Mobility Providers (EMP)
- Distribution System Operators (DSO)

1.3 Other project deliverables that may be of interest

The following public project deliverables might be useful for the reader to get a more comprehensive view on the conditions, specifications and planning of the Oslo pilot:

- *D2.2 Revised Strategic Plan for Pilots* - deliverable describing refined user needs and requirements and the revised plan for pilots based on intermediate evaluations and lessons learned from the pilots.
- *D2.3 Description of Oslo Pilot and User Needs* - document describing the Oslo pilot in terms of challenges, user needs, use cases, scenarios, stakeholders and locations to be involved and the baseline.
- *D2.4 Implementation Plan for Oslo Pilot* - document describing the planning of the tests to be carried out at the pilot site. It includes scenarios to be demonstrated, time schedules, stakeholders and locations selected, users selected for workshops and for testing, hardware and software to be installed, tests to be run and data to be collected, etc.
- D2.5 *Pilot Component Preparation for Full-Scale Pilot (Oslo)* - deliverable describing the deployment and the testing of software and hardware components to be used in the pilot, to prepare for the full-scale pilot implementation.
- D2.6 *Full-Scale Pilot Implementation in Building Block* - document describing the implementation of the Oslo pilot. This includes the specifics of the hardware and software components used in the Oslo pilot. The deliverable D2.6 itself is the Oslo pilot.
- D2.7 *Technical Monitoring Report and Feedbacks (Oslo)* - deliverable presenting the intermediate results from the Oslo Pilot with its three demonstrators.

This deliverable (D2.8) describes lessons learned from the Oslo pilot. The lessons learned from the two other pilots in GreenCharge are described in:

- D2.15 *Final Report for Bremen pilot: Lessons Learned and Guidelines*
- D2.21 *Final Report for Barcelona Pilot: Lessons Learned and Guidelines*

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The merged deliverable D5.5/D6.4 *Final Result for Innovation Effects Evaluation / Stakeholder Acceptance Evaluation and Recommendation* includes the overall evaluation of the GreenCharge project. This includes evaluation of 1) the seven GreenCharge demonstrators; 2) simulation scenarios; and 3) the software implemented in the project and the research data collected from demonstrators. D5.5/D6.4 includes both impact and process evaluation of the demonstrators.

1.4 Other projects and initiatives

GreenCharge is a project under the CIVITAS umbrella of projects, and the evaluation as reported in D5.5/D6.4 is based on the CIVITAS process and impact evaluation framework.

INVADE is a Horizon 2020 project with the goal of increasing the share of renewables in the smart grid (INVADE H2020, 2019). ESMART is an INVADE project partner and the *eSmart Connected Prosumer* is a flexibility management system made for and in INVADE. This software, with required adjustments, forms the basis of the Neighbourhood Energy Management System (NEMS) for the Oslo Pilot and is a part of ESMART's input to the GreenCharge project.

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2 Objectives

2.1 How were the objectives achieved?

This section describes how the objectives were achieved in the Oslo pilot. The Oslo pilot comprises three demonstrators: OSL.D1, OSL.D2 and OSL.D3. Note that OSL.D3 is solely implemented to collect data regarding energy consumption in flats and does not have any direct interaction with users.

The GreenCharge objectives for the Oslo demo are as follows[2]:

O1. How new **business models** with an intelligent billing system can take consumer acceptance and ownership into account
O2. How a **booking system** for charging services can be directed towards certain costumer groups
O3. How to facilitate for **cost-efficient home-charging** in housing associations with limited grid capacity
O4. How an **integrated smart charging solution** can balance charging of EVs with local energy use and electricity production
O5. How the **user interface** and services for EV charging will work in different situations and for different user groups.

The following sub-sections describes how the objectives were addressed in the three Oslo demos:

2.1.1 OSL.D1

Oslo demo 1 (OSL.D1) addresses objectives O1, O3, O4 and O5 by enabling smart EV charging in the common garage facilities at Røverkollen housing cooperative. The smart charging system (O3 & O4) ensures that the utilisation of the local RES for EV charging is maximised. The system accounts for variable electricity prices (in the electricity market), peak power tariff and locally available (and free of charge) solar photovoltaic (PV) electricity. For the system to plan the charging, detailed information from the EV users is required. In the developed ZET.Charge app (O5), the EV user enters information on the battery size, and for each charging session enters three values:

1) SoC when connecting,
2) desired SoC at departure and
3) estimated departure time.

Based on this information, the required amount of energy to be provided is calculated. Together with knowledge on next day's electricity prices, estimated solar PV electricity production and estimated electricity use within the building (garage), the smart charging system finds how much each car should be charged at what time. In other words, the system decides the optimal time for charging and at what charging speed (capacity), ensuring that:

- The cars are charged with as much local RES as possible and at the lowest possible charging-cost,
- the peak load of OSL.D1 (total garage) is kept as small as possible – alleviating grid burden and saving grid costs for the Røverkollen housing cooperative.
- The requested charging demand is met (both the requested amount of energy and that the car is fully charged at the time of departure).

The user interface in the GreenCharge smartphone app (ZET.Charge app) have been developed in several steps, allowing for feedback from the users regarding user-friendliness and errors. The first test was done in summer 2021, and minor adjustments of the app (both user interface and back-end software) have been necessary until the project finalisation. The latest update of the app was pushed in the beginning of Feb 2022.

In OSL.D1 **cost-efficient home-charging** (O3) and **integrated smart charging solution** (O4) is supported by a new viable **business model** (O1). The business model of OSL.D1 is described in deliverables D3.4 (Chapter 3.2.1) and D5.5. A flat pricing in NOK/kWh for EV-charging is applied, and the optimal charging system (O3

[2] These are redefined based on the project's specific objectives (see the DoA) to describe the scope of the Oslo pilot.

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& O4) ensures that the EV is charged at the lowest possible cost and with the greenest possible electricity. The housing cooperative provides the charging service to the residents with a non-profit aim, i.e. least-cost principle. As the investments of the local renewable energy sources (RES) are sunk costs, maximising the utilisation of the local RES also ensures lowest possible expenses for electricity bought from the power grid. The housing cooperative uses the income from the EV-charging to pay the electricity bill of the garage. The charge point operator is FORTUM who receives the payment of the EV charging and passes on the payment to the housing cooperative. In return, FORTUM, ESMART and ZET receives a cut of the charging cost. The exact cut will be settled based on commercial discussions after end of the project.

A version of the business model allows for choosing either flexible or priority charging. If the EV user is in a hurry she may choose priority charging, which starts the charging momentarily, at an extra cost. Whereas flexible charging would allow the optimisation system to charge the EV in the most cost-optimal and greenest way (as described above).

2.1.2 OSL.D2

Oslo demo 1 (OSL.D2) addresses objectives O1, O2 and O5 through the deployment of charging services on four publicly available outdoor parking places at Røverkollen housing cooperative. The four charging points (CPs) are owned by Røverkollen, but are made available for visitors and other EV users, e.g. employees at the nearby school or users of the outdoor sport facilities next to Røverkollen. Hence, the outdoor chargers can be used by residents at Røverkollen, as well as other EV users. The charging service is provided by FORTUM, ZET and HUBJ in cooperation (see details in Section 2.3.2).

The core of OSL.D2 is the booking system (O2) provided by the ZET.Charge app. Once installed on a smart phone, the ZET.Charge app (O5) provides the possibility to book a charging point at Røverkollen prior to arrival. This provides a remedy against charging anxiety for EV users as they can book a charging point while (or prior to) driving to their destination.

By design the same ZET.Charge app is used for both OSL.D1 and OSL.D2.

OSL.D2 addresses the business model objective (O1) by establishing a viable business model for offering charging services on four publicly available outdoor parking places at Røverkollen housing cooperative.

2.1.3 OSL.D3

As previously described, OSL.D3 was implemented solely to collect data regarding energy consumption in flats. It was established since it was not economically beneficial, due to regulatory constraints, to include energy consumption in the apartments into the neighbourhood energy management system (NEMS) of OSL.D1. The collected data is used for simulation purposes, enabling the project to evaluate the effects of introducing a full NEMS, and thereby supporting the objectives regarding lessons learned.

2.2 Deviations from the objectives during the project phase

The project's deliverable *D2.2 Revised Strategic Plan for Pilots* describes refined user needs and requirements for the pilots and provides a revised plan for the last iteration of the pilots. This section describes the deviation of the objectives as described in D2.2.

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The objectives as described in D2.2 are as follows:

Technological objectives:

- GreenCharge will investigate how home-charging can be made cost-efficiently available in a garage where most residents have their own parking space. Initially, the parking garage had limitations in the grid capacity. After replacing the electric transformer, capacity is increased.
- Energy Smart management is developed to manage charging utilising solar power, battery storage and load balancing.
- Booking systems for charging services is developed to open access for external users, visitors, as well as residents with special needs for charging.

Business model objectives:

- Business models will be developed to secure sustainable value chains for EV-users, Charging Point Operators (CPOs) and other stakeholders. These will include an intelligent booking and billing system taking consumer acceptance and ownership into account.
- Surveys among users, stakeholders and the local reference group will be conducted to investigate how the user interface and services for EV charging will work in different situations and for different user groups.

Compared to the objectives described in the previous section, the content of the objectives has not changed significantly. It is mainly the wording so that the objectives are stated in a clearer way.

Through the project, it was necessary to do adjustments to the original plan of the pilot. The adjustments made are linked to the following topics:

- Pilot application: A housing cooperative (representing individual users), instead of individual users living in apartments
- Orchestrator of the business model
- Ownership of assets
- Integration of software

Each of these topics are described in greater detail in the following:

The Oslo **pilot was applied** to a housing cooperative in the suburb of Oslo. A housing cooperative is a legal entity that provides services to the residents (here 246 apartments) such as: Parking facilities, provision of hot tap water, maintenance of the common areas of the apartment blocks (e.g. stairways and elevator), maintenance of common outdoor areas (e.g. pedestrian walkways and play grounds). The cooperative is a non-profit organisation, i.e. an entity that does not make profit on its residents, but provides services to the residents to minimum costs. Further, according to a new Norwegian law that came into force on 24th Nov 2020, the cooperative has the responsibility for providing charging facilities for its residents.

For a **business case** to become successful it should have a growth potential, meaning that the orchestrator of the business model can replicate the business model from the demo and offer it to other housing cooperatives. In this perspective, the natural orchestrator (selected among the GreenCharge partners) would be FORTUM. At the time of the project application, the business unit *Fortum Charge & Drive* already provided charging services (both public and private) in Norway and Sweden. However, during the project period, FORTUM endured several restructurings. The public charging network was moved to a new entity, *Recharge*, and the majority ownership of this entity was sold to a separate company. Further, the software department, providing the backend system to the public as well as the private charging, was transferred to a new daughter company called *Plugsurfing*. The third part, i.e. the private charging and the electric mobility provider (EMP) solution, remained as *Fortum Charge & Drive*. Hence, the interests of FORTUM changed, and the possibilities to adopt

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special solutions for private charging entailed separate daughter companies with different business goals was not realistic.

Therefore, during the GreenCharge project, the **orchestrator** of the business model changed several times, but was finally decided to be the Røverkollen housing cooperative. The benefit of this is that the housing cooperative administers the charging service that is offered to the residents. The drawback is however that the cooperative does not have an interest to expand and replicate the business model for providing charging as a service to other housing cooperatives, preventing further growth.

Ownership of assets. OSL.D1 entails roof-top PV and a stationary battery that are financed by Oslo municipality but is owned by the housing cooperative. In a normal business model, the orchestrator would pay for all the assets in the demo. However, as Oslo municipality was one of the project partners, they had incentives to showcase the possibility of utilising local on-site RES in a smart charging system and decided to fund these two assets. Today, the municipality uses the GreenCharge demo as a showcase for green and smart charging, and the experiences from the demo are utilised for developing local policy on facilitating charging possibilities for people living in apartment blocks in city centres.

Integration of software. It became apparent in the middle of the project (Q3-2019) that FORTUM could neither take on the role as business orchestrator nor as the main software supplier as intended in the project proposal. The result was that ZET took on a greater role regarding software development by 1) developing the ZET.Charge app and 2) enabling the integration of the back-end systems of FORTUM, ESMART and ZET in OSL.D1, and of FORTUM, HUBJ and ZET in OSL.D2.

2.3 Results based on the objectives (DoA)

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

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

The results within each topic are further detailed in the next three sections (Section 2.3.1, Section 2.3.2 and section 2.3.3)

2.3.1 Evaluation results and lessons learned (R_ELL)

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

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

In addition, the Oslo pilot, in OSL.D3, collected research data to support simulation of two additional scenarios (*Scenario 5: V2G* and *Scenario 6: Reacting to demand response request*). Table 3 below describes how these innovation scenarios were implemented in the Oslo pilot (the results), and which objectives the results contribute to. (See deliverable *D2.6 Full-Scale Pilot Implementation in Building Block* for the specifics of the hardware and software components used in the Oslo pilot).

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Table 3: Innovation scenarios mapped to results for Oslo pilot

Innovation scenario #	Results from OSL.D1	Results from OSL.D2	Contribution to objectives
1. Charge planning and booking	• Smartphone app enables user to input expected SoC at departure time ("energy booking") • NEMS optimises use of RES according to "energy bookings"	• App enables booking of charge point	(O2) *booking system* (O4) *integrated smart charging solution* (O5) *user interface*
2. Charging at booked Charging station	• App allows user to choose flexible or priority charging	• App enables start/stop of charging at booked charge point • Payment through app or by roaming (eRoaming) agreements	(O1) *business models* (O2) *booking system* (O4) *integrated smart charging solution* (O5) *user interface*
4. Home charging in older (groups of) residential buildings with common internal grid and parking facilities	• 65 charge points installed in garage • NEMS supports load shifting and reduces grid load • Integration of solar energy and battery storage in NEMS		(O1) *business models* (O3) *cost-efficient home-charging* (O4) *integrated smart charging solution*

2.3.2 Results of Business models (R_BM)

For the Oslo pilot, business models have been developed that secure sustainable value chains for EV-users, charging point operators (CPO) and other stakeholders. These business models have been developed based on consultations (in workshops) with the relevant stakeholders for the Oslo demonstrators: Røverkollen (housing cooperative), residents, visitors, DSO/energy retailer, CPO, and the local reference group.

2.3.2.1 Business models for OSL.D1

The business model for OSL.D1 is illustrated in Figure 1. Røverkollen, as the orchestrator, connects all stakeholders in the ecosystem and exchanges information, energy and cost and revenues. This way, Røverkollen provides smart charging solutions powered by local renewable energy to its residents. The following key elements and assets are bundled by the orchestrator:

1. Photovoltaic panels and battery storage: Producing and storing PV energy
2. Charging infrastructure and grid connection in the garage: Distribution of energy within the garage to the charging points
3. Payment and billing system: User-friendly and secure payment and billing process
4. Energy management system: Distribution of the mix of grid energy and local renewable energy and enabling smart charging solutions
5. ZET.Charge App: Enabling users to charge based on their individual energy demand and flexibility, resulting in higher tariffs for faster priority charging in comparison with the default charging mode

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

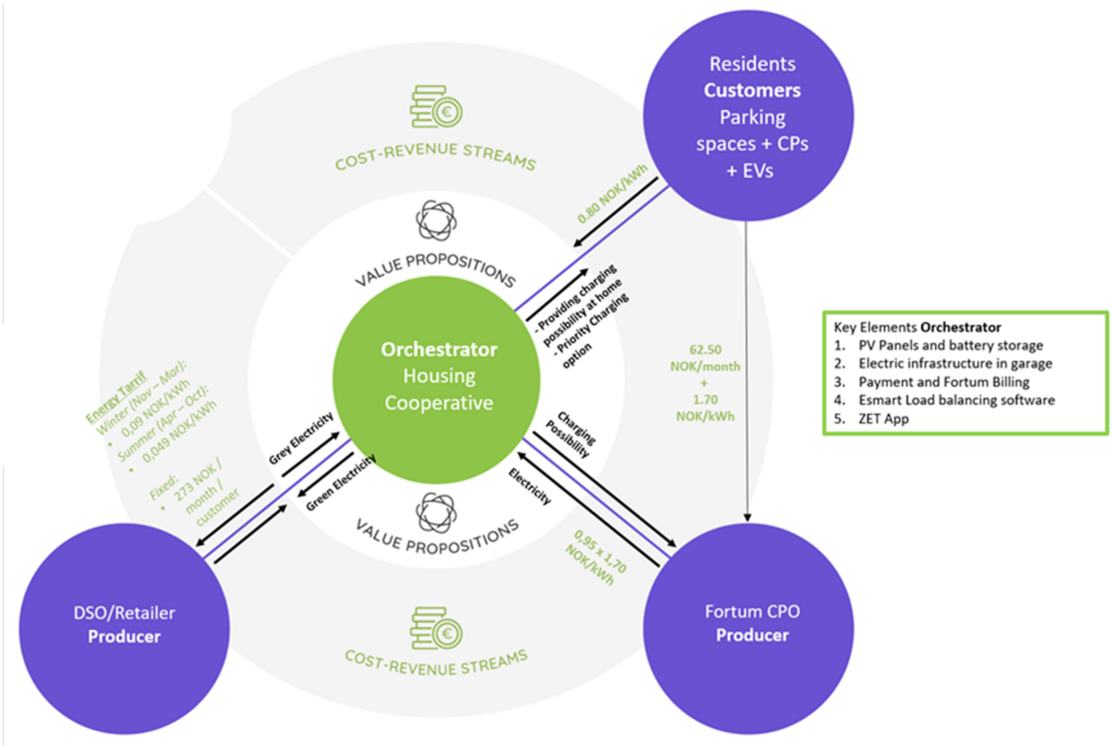

Figure 1: Business model for OSL.D1

All of these elements are interlinked, and each individual element adds value to the ecosystem as a whole. As a result, the captured value can be maximised by making the best use of local renewable energy. The orchestrator bundles these elements so it can provide a complete smart charging service. The residents are stimulated through the business model to utilize be more flexible charging mode, resulting in a lower peak demand (and less need for grid investments).

A more comprehensive description of the business model developed for OSL.D1 can be found in deliverable *D3.4 Final Business Model Designs*.

2.3.2.2 Business models for OSL.D2

The business model developed for OSL.D2 is illustrated in Figure 2. For this demonstrator, Røverkollen as the orchestrator provides charging solutions to its visitors. Røverkollen bundles the following key elements and assets:

1. Charging infrastructure outside the garage
2. Payment and billing system: User-friendly and secure payment and billing process
3. ZET.Charge app for visitors: Enables visitors to book their charging point in advance
4. Roaming interoperability: Visitors can plug in and charge up instantly using automatic EV-to-charging station authentication technology, without apps or RFID cards

All of these elements are interlinked, and each individual element adds value to the ecosystem as a whole. As a result, the captured value can be maximised by maximising the utilisation of the charging points through offering real-time availability information and booking options. Visitors can book their charging point in advance so they know before arriving whether they can charge or not.

In addition, the business model includes a blocking fee for EV users that block the CP after the end of the booked time slot. This way, Røverkollen wants to make sure that EV users do not exceed their booked time slot and other EV users can assume that the CP is actually available (as shown in the booking app).

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

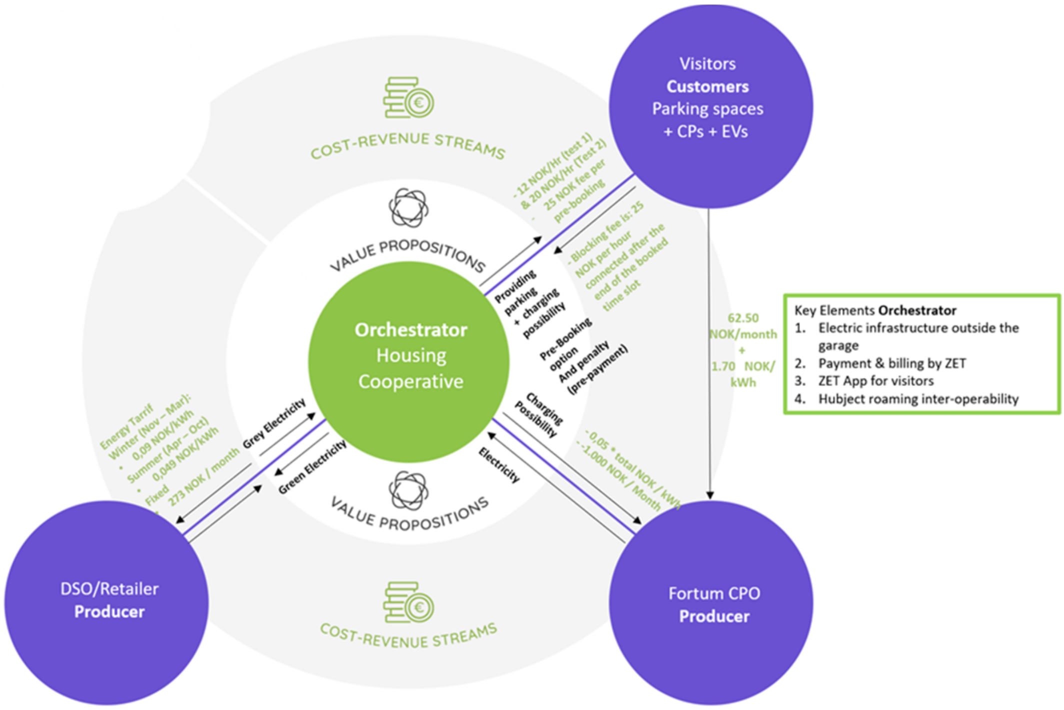

Figure 2: Business model for OSL.D2

2.3.3 Results of Technology Prototypes (R_TP)

This section presents the prototypes developed in the Oslo demonstrator. The section is divided into the following four technologies:

- Neighbourhood energy management system (EMS) provided by ESMART
- Charge management system (CMS) provided by FORTUM
- ZET.Charge app and smart charging algorithm provided by ZET
- ZET.Charge app as an EMP provided by ZET
- Roaming provided by HUBJ

2.3.3.1 Neighbourhood energy management system (NEMS)

The NEMS coordinates 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. ESMART calls its NEMS *eSmart Connected Prosumer*, and a simplified structure of this is illustrated in Figure 3 below. In general, the NEMS architecture provides a solution architecture for:

- The NEMS **creates optimal control plans** for how the flexible assets such as the stationary battery and charging points should be utilized. Based on forecasted conditions of the next 48 hours, the NEMS uses data on the requested charging demand, what flexibility is available and the customer's contracts with grid operators and retail contracts, to optimize the usage of PV production, loads, storage and charging to reduced grid and retail costs through the use of the flexibility available in the system.
    - The optimal control plans are sent to the external systems that implement these by sending the control commands to the assets under their control. (In GreenCharge: ZET receives the plan and passes the optimal charging power to FORTUM who sends the signal to the Schneider CPs)
    - Note that for this project individual charging points were not controlled by the NEMS, rather an optimal control plan for each zone in the garage of OSL.D1 was produced and the local control of the charge point assets within that plan was set by ZET. However, the control of the battery was included in NEMS control plans.

- The NEMS captures **historic data** such as meter readings, charging session readings, battery level readings, weather and contract prices and any other time series type of data. Additionally, as part of GreenCharge, data capture was extended to also capture data related to charging point bookings.
- The NEMS uses **artificial intelligence (AI)** to make the 48 hours forecast of electricity generated by PV and electricity consumed, including charging profiles (taking account of history and booking data). Hence, the forecast is based on historic data, as well as forecasted weather data and day-ahead electricity price (when relevant based on contractual agreements).
- The NEMS captures **contractual arrangements** related to energy supply and grid operations (supply and grid contracts) and the **financial arrangements** in terms of how the energy is charged to the customers.
- The NEMS captures **assets** and the relationship between assets and asset operational data such and min and max constraints. Additionally, data related to how the asset can be controlled and what flexibility is available is captured. The assets include both physical assets such as batteries, charging stations, PV, various load types, thermal storage, and virtual assets such as pricing zones.

NEMS is delivered as a cloud-based solution (powered by Microsoft Azure) with a web UI for maintaining and managing the associated data and viewing and maintaining time series data associated with the assets and contracts. Additionally, there are various restful APIs, event hubs and IoT hubs that are provided to integrate data flows to and from the NEMS (such as meter readings into NEMS and control plans out of NEMS). The data formats are based on ESMART's proprietary standard data integration formats (via JSON). For GreenCharge the restful API integration approach was utilized. Internally within the NEMS solution various services are run in a queue based scalable architecture to perform calculations, conversion, aggregations, predictions (with AI) and optimization. An overview of the architecture is provided in Figure 3 below.

The main adaptations/updates done for GreenCharge were the development and implementation of:

- Receiving session information through the integration API. This includes Bookings Start, Stop and Energy required and transaction parameters.
- Algorithms to convert and merge data from the previous point into time series data suitable for optimization.
- Export of data mapping the optimization data into data series that can be consumed by the external integration partners for the battery regulation.

Additionally, a lot of support and implementation assistance was provided to load the relevant data such as the assets, contracts, prices and operations data and integration mapping data to enable the end-to-end solution to be operational.

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

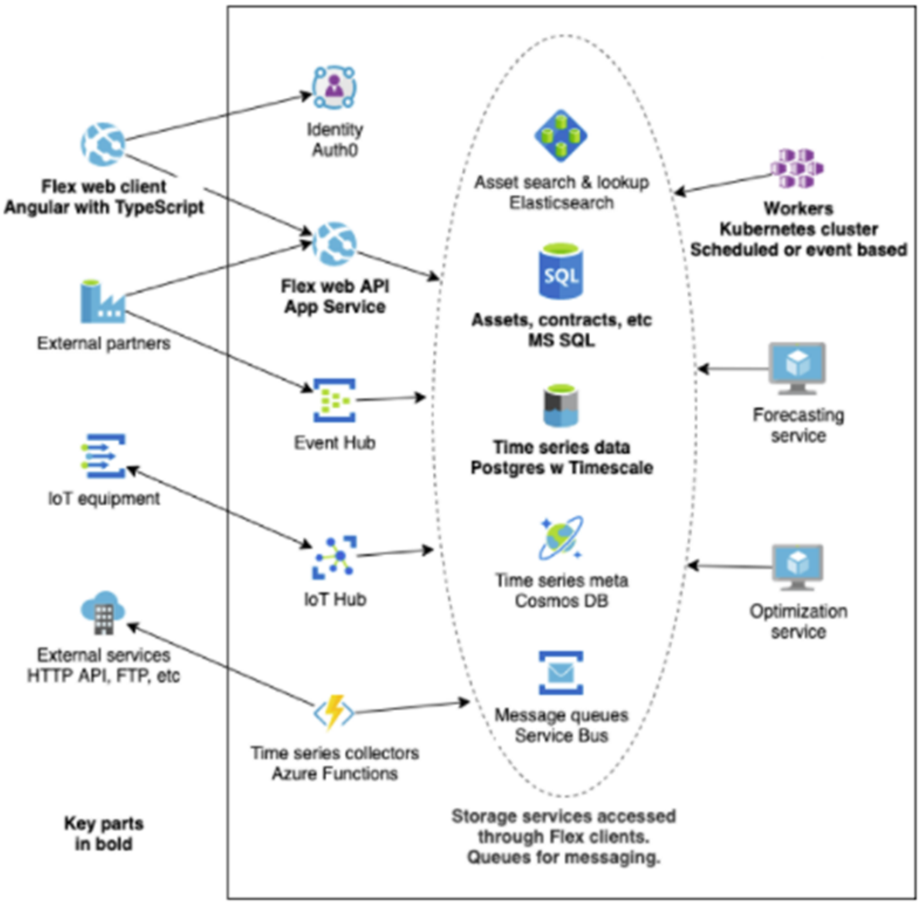

Figure 3: eSmart Connected Prosumer architecture

2.3.3.2 Charge management system (CMS)

The CMS is responsible for managing the charging points and providing charging services. This is typically implemented as a software platform that allows Charge Point Operators (CPOs) to control EV chargers remotely. FORTUM calls its CMS for *Charge & Drive Management Cloud* (CDMC), and a simplified structure of this is illustrated in Figure 4. For the GreenCharge project, the system can be simplified and described in four parts:

- A charger-server bridge, that enables the communication between the chargers and FORTUM's servers;
- Authentication and payment services, that enables users to register, add payment method and start and stop charging with RFID
- A web admin portal, that provides the CPO with information regarding charger status and charging sessions, and need for maintenance and customer support;
- A smart charging API, which is exposing session data (starts, stops and metering values) to the other stakeholders. The smart charging API was developed specifically for the GreenCharge project.

The main adoption/update done for CDMC for GreenCharge OSL.D1 is the development and implementation of the Smart Charging API:

- Send session information through the API: Start charging, stop charging and metering values, with relevant charger, session, and transaction parameters.
    - Integration with ESMART and ZET.

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

- Receive specific values of current (Ampere) for specific charging stations through the API. CDMC thereafter sends through the steering commands to each charging station.
    - Integration with ZET.

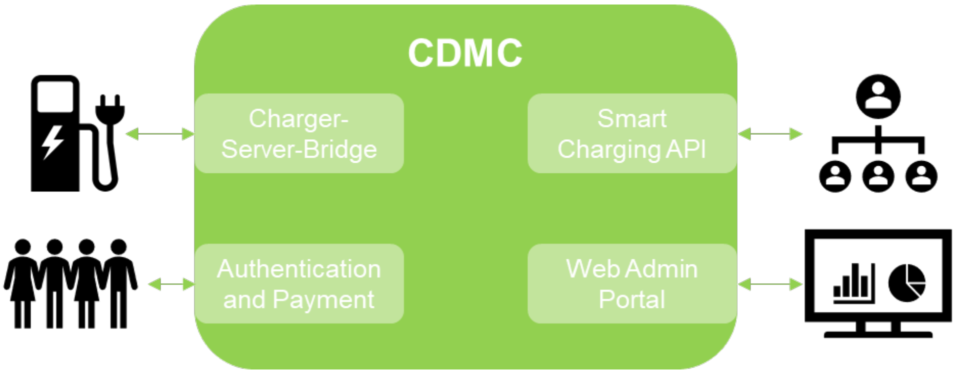

Figure 4: Simplified structure of CDMC

2.3.3.3 ZET.Charge app and smart charging algorithm

The ZET.Charge app is used to retrieve important basic data for planning the charging process in OSL.D1. During the registration process, the user is asked to provide information about the vehicle he or she is using. This includes in particular the vehicle model and the battery sizes (in kwh).

The query of the charging preferences takes place in several steps:

1. Users are asked to select the vehicle they want to charge. This step is important to calculate the required amount of energy as different cars have different battery sizes.
2. In the second step, the users are asked to set the state of charge of their vehicle via the slider control
3. Subsequently, the desired departure time is selected via the "Select Date" button.
4. Also important is the query of the desired state of charge at the selected departure date
5. In a final step, the user can select the additional option "priority charging". This additional service guarantees the fastest possible charge of the electric vehicle

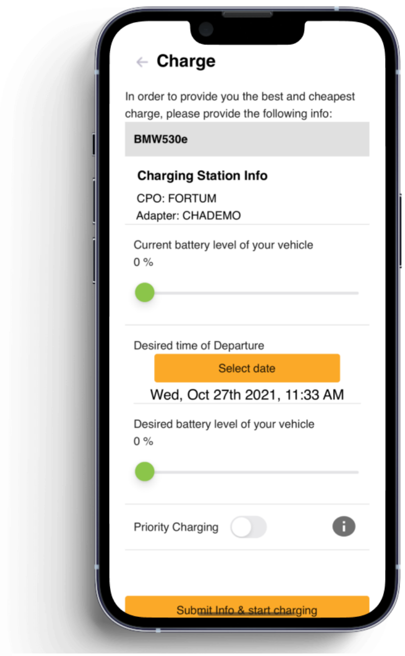

Figure 5: Screenshot ZET.Charge App

The collected user data is sent to the NEMS system, as described above, to enable calculation of the energy demand. The NEMS system provides a calculation of the available energy within the different zones of the garage every 15 minutes. The value sent is used by the smart charge algorithm to control the charging process according to user preferences. In the flexible tariff, charging takes place in an ampere range between 0 and 32A, charging can be paused here and resumed at a more optimal time always within the time window selected by the user. The highest possible value is output in the priority tariff.

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

2.3.3.4 ZET.Charge app as an EMP

The ZET.Charge app takes over the role of the EMP for the demonstrator OSL.D2. Via the integrated map, charging points available via the Hubject network are displayed. The ZET.Charge app processes both user requests for authentication to start charging processes and the payment of completed charging processes.

In addition, for the four charging stations of the demonstrator there is the exclusive possibility to book the charging point in advance. This is possible because these charging points are exclusively accessible via the ZET.Charge EMP solution.

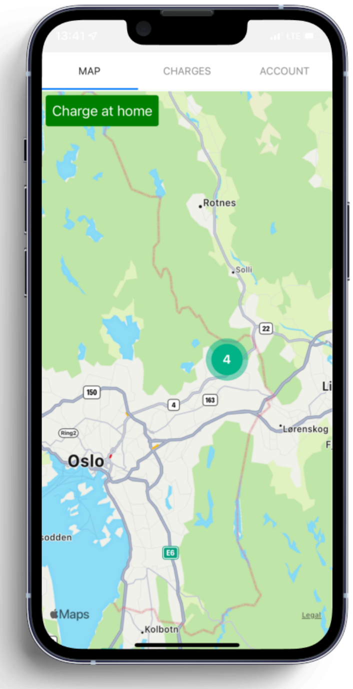

Figure 6: Screenshot ZET.Charge Map

2.3.3.5 Roaming

Roaming (or eRoaming) offers EV drivers the option to charge their vehicles at all charging stations – regardless of any contracts concluded with operators. This is implemented by a roaming management system that supports seamless payment and booking, also for shared private charging points (including utilisation of V2G). The roaming management system allows for seamless connection between CPO’s and Electric Mobility Providers (EMP) who are on the platform without the need of individual contracts between each and every partner. It also allows for features like “book now” and settlement between the partners for the charging sessions.

In GreenCharge, roaming is implemented through HUBJ's brokering systems (HBS). The Figure 7 below shows how the charge point is made available to the EV driver.

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

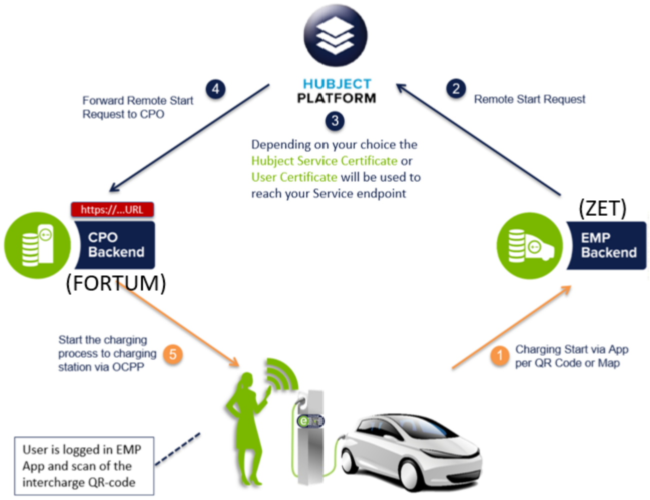

Figure 7: The flow and exchange of messages for the authorisation of the charge point

3 Operation of the Oslo Pilot

3.1 Description of the demonstrators

3.1.1 General description of demonstrator sites

The Oslo pilot comprises the following demonstrators (see Figure 8):

1. OSL.D1 - "Energy Smart Neighbourhood Charge Point Demo"
2. OSL.D2 - "Charge Point Operation Demo"
3. OSL.D3 - "Measurement of ESN apartments Demo" – this is used to collect data to enable simulations for impact assessment of ESN

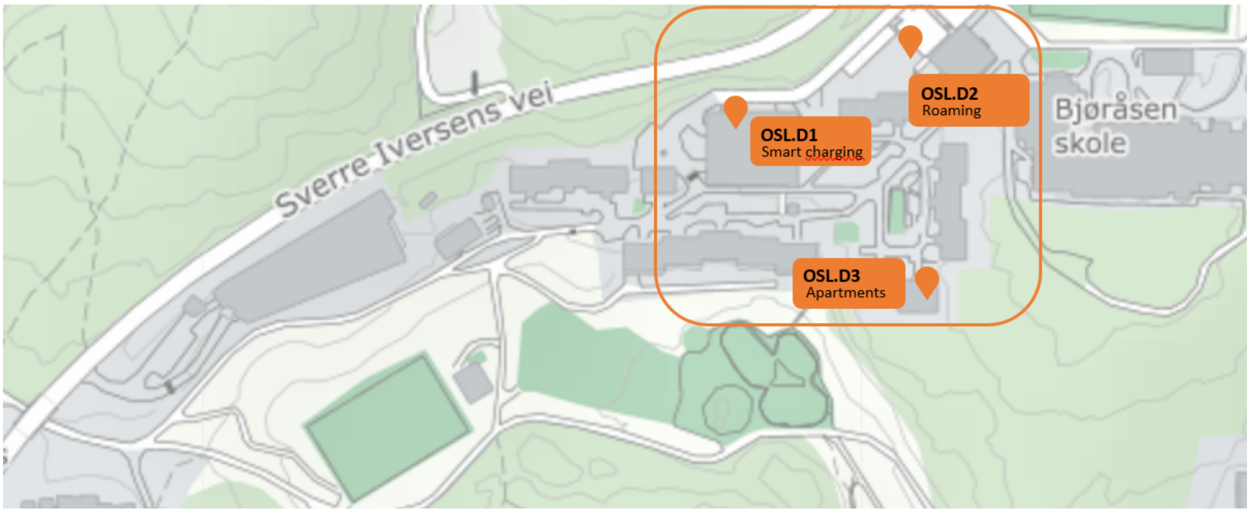

Figure 8: The demonstrators at the Oslo Pilot

The planning and implementation of the three demonstrators are detailed in the following deliverables:

- *D2.3 Description of Oslo Pilot and User Needs* - this document describes the Oslo pilot in terms of challenges, user needs, use cases, scenarios, stakeholders and locations to be involved.
- *D2.4 Implementation Plan for Oslo Pilot* - this document describes the planning of tests to be carried out. This includes scenarios to be demonstrated, time schedules, stakeholders and locations selected, users selected for workshops and for testing, hardware and software to be installed, tests to be run and data to be collected, etc.

3.1.2 Description of deployed hardware and software

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

- *D2.5 Pilot Component Preparation for Full-Scale Pilot (Oslo)* - this deliverable describes the deployment and the testing of software and hardware components to be used in the pilot, to prepare for the full-scale pilot implementation.
- *D2.6 Full-Scale Pilot Implementation in Building Block* - this document describes the implementation of the Oslo pilot. This includes the specifics of the hardware and software components integrated and used in the Oslo pilot. The deliverable D2.6 itself is the Oslo pilot.

A summary of the deployed hardware and software is shown in Table 4 below (*Source: D2.6 Full-Scale Pilot Implementation in Building Block, Section 2.1)*.

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

Table 4: Hardware and software used in Oslo demonstrators (from D2.6)

Service	Component name	Description	Demo site	Type	Partner
Charge Service Provisioning	ZET.Charge	The GreenCharge application ZET.Charge is the digital interface towards the user	OSL.D1 OSL.D2	SW	ZET
	Payment system	System for billing and payment of charging sessions	OSL.D1 OSL.D2	SW	FORTUM ZET
	Booking system	Enables visitors to pre book a time slot for a charge point via app	OSL.D2	SW	ZET
Roaming	Hubject eRoaming	eRoaming between Fortum CPO system and ZET EMP system via eRoaming	OSL.D2	SW	HUBJ
Fleet management system	N/A	-	-	-	-
EVSE[3]	Charge point infrastructure in garage	Charging points installed at privately owned parking spots in the parking garage. Will be used by residents of the housing cooperative	OSL.D1	HW	OSLO
	Outdoor public charging station	Charging points installed outdoors, to be shared/used by visitors	OSL.D2	HW	OSLO
Charge station operation & EV charging	Charge mgmt. System (CMS)	Fortum Charge & Drive (CDMC)	OSL.D1 OSL.D2	SW	FORTUM
	Algorithm for Smart Charging	ZET Algorithm for Smart Charging Local control system managing the charging process of a charging station based on input from NEMs	OSL.D1	SW	ZET
Local energy management	eSmart Connected Prosumer	Forecast of the energy demand needed to properly plan the assets. The forecasting is done based on historical energy demand information and context variables such as weather forecast and calendar Calculates the optimal schedule of all loads and local RES for the optimization criteria defined and user preferences	OSL.D1	SW	ESMART
	Local Renewable energy source	PV panels installed on the roof of the parking garage. To enable locally produced energy. Will be stored in the stationary battery	OSL.D1	HW	OSLO

[3] EVSE - E-vehicle supply equipment

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

	Local battery storage	The stationary battery stores the electric energy generated by the PV panels. To be used e.g. when charging EVs	OSL.D1	HW	OSLO
	Battery mgmt. system	Battery mgmt. System to be integrated with NEMS in order to push meter values for PV and battery and to receive control signals from NEMS	OSL.D1	SW	OSLO

3.1.3 Systems developed and/or extended from existing background

The implementation of the demonstrators at the Oslo pilot in GreenCharge required both new developments and extension/modification of existing components. This is summarized in Table 5 below. See deliverable D2.6 for details.

Table 5: Systems developed and/or extended from existing background

Service	Component name	Before GreenCharge	After GreenCharge	Partner
Charge Service Provisioning	ZET.Charge	-	New developed charging app available for iOS and Android.	ZET
	Payment system	-	New developed payment system as part of the ZET backend. It incorporates data from FORTUM regarding charging sessions provided though HUBJ's eRoaming platform	FORTUM ZET HUBJ
	Booking system	-	New developed booking system enables the user to prebook a public charge point. It is part of the ZET EMP Solution.	ZET
Roaming	HUBJ eRoaming	Allowing access to all the charge points on the HBS system without the need for any special bilateral connection between the CPO and EMP. Prior to GC the protocol used was OICP 2.2.	Enhancement of the protocol to find the exact duration of charging in a session, see the amount of energy charged during the charging process, introduced a penalty start time in the protocol in the case of a charge point blocking, allows EMP's to filleter charge points based on the use of renewable energy.	HUBJ

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

Fleet management system	N/A	-	-	-
EVSE	Charge point infrastructure in garage	-	65 charge points installed	OSLO
	Outdoor public charging points	Old charging points (not OCPP compliant)	4 new charging points installed (OCPP compliant)	OSLO
Charge station operation & EV charging	Charge mgmt. System (CMS)	Charge mgmt. System for connecting chargers and users, allowing starts and stops, energy flow, billing etc	New developed API that sends through start and stop messages as well as meter value data to an external partner, as well as allowing the partner to send specific limits of current for each charger, which are sent through to the charger as steering commands.	FORTUM
	Algorithm for Smart Charging	-	This new developed charging algorithm distributes the assigned energy amount calculated by the NEMS to the individual charges based on the users' preferences.	ZET
Local energy management	eSmart Connected Prosumer	Energy Smart Neighbourhood (ESN) solution for optimization of flexibility to reduce costs within the constraints of the assets and contractual arrangements through utilization of flexibility	Extend set up for Bookings Integration (start, stop, energy required level), Conversion and Integration into Optimization Conversions of data to integration requirements required by external partners for integration	ESMART
	Local renewable energy source	-	PV panels installed (total peak capacity 70 kWp)	OSLO
	Local battery storage	-	stationary battery was installed capacity of 50 kWh	OSLO
	Battery mgmt. system		*Part of stationary battery delivery*	OSLO

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

3.2 Operation of the demonstrators

Compared to the baseline as described[4] in project amendment, the implementation of the demonstrators was delayed. With reference to milestone *MS7 Ready for pilot and evaluation phase 2*, dated January 2021, the last demonstrators in Oslo were activated 16th Feb 2022, hence, the demonstrators have only been running for a very short time. The reason for these delays are summarized in Table 9 on page 38.

OSL.D1 was activated on 7th Feb 2022 for the 4th floor, and the other floors (1st-3rd) were activated on 16th Feb 2022. The first activation on the 4th floor of the garage included seven charging points. After one week, the rest of the garage was included. During the first few days of the rollout an issue with the optimal power value (from the NEMS) sent to the CP (through the CMS) was discovered. Although the issue was quickly solved by ZET and FORTUM, the problem was not possible to detect without charging an EV using the app at the charging point. In this case, the issue was discovered by the chairman of the board at Røverkollen when he charged his car. This again shows the importance of doing live on-site testing, since many of the error or bugs only can be discovered when charging an EV using the App.

OSL.D2 was activated on 16th Feb 2022.

Until activation of OSL.D1, the CPs were connected to an off-the-shelf LMS system. In this time frame, an RFID chip could be used to start/stop charging, and the electricity from local roof-top PV was either used directly for EV charging or exported to the local grid.

The purpose of the solar panel system is to use locally produced electrical energy to avoid local power grid overload during EV-charging (keep power demand under the limit of 217 kW in the garage). The solar panel system was planned to be integrated with the stationary battery, the NEMS and CMS. The energy generated through the PV panels at daytime will be stored in the stationary battery and used when EVs require charging. When the NEMS and CMS are activated, the battery receives controls signals from NEMS and shall act accordingly. During integration testing of the battery (06.01.2021), it was discovered that the NEMS was not able to read SoC from the battery. This has been identified as a malfunction of the battery controller. The sub-supplier is currently working on this issue. This means that, for the time being, the NEMS is not able to generate a charge/discharge plan for the battery.

During the operation of OSL.D1 a snowfall resulted in snow covering the PV panels, resulting in less energy generated from the panels. This is a common issue in Norway and is shown in Figure 9.

[4] AMD-769016-23 amendment which includes extension of the project duration with 6 months due to COVID-19 pandemic

Figure 9: Photo of PV panels covered by snow

The ZET.Charge app have been under development until the activation of the demonstrators (both OSL.D1 and OSL.D2). The final version of the app was released in the end of January 2022. The residents at Røverkollen were given a link to download the new app and given an updated user manual for how to charge at their private charge point and at the public charge points.

There have not been large deviations from the original plan regarding functionality of the app. The application was planned to include the following:

- start and stop charging,
- payment for charging according to local price structure and to choose priority booking for a price increase if preferred
- data fields regarding need for charging, e.g. state of charge, time of departure and energy requirement to fulfil mobility needs for next trip
- The app should also have interface for entering customer data, such as vehicle, battery capacity and charging speed

All of these requirements were fulfilled in the final version of the app. The main challenge was that the app was not completed until February 2022, resulting in less collected usage of the app than planned for.

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

4 Measures and KPI's

4.1 Measures implemented in the pilot

For the Oslo pilot at Røverkollen three measures were decided related to the key performance indicators (KPIs):

- OSL.D1 - Private Charging in Garage: The aim is to investigate how home charging can be made smart, flexible and cost-effective using locally produced energy.
- OSL.D2 - Outdoor chargers: Sharing of private outdoor CPs. Roaming, booking and sharing of charging points will be demonstrated here.
- OSL.D3 – Data collection on energy consumption: Collecting data in the neighbourhood via sensors and meters installed in apartments and on hot water heaters. Data was used for simulating a complete ESN.

4.1.1 Implementation of charging measures in OSL.D1

The following hardware installations are done to facilitate the charging:

- Charging points (CP) at parking places in the garage. All residents were offered to purchase CPs. In total 65 CPs where installed.

The app is used to facilitate the charging measures and provide input on:

- Information about the electric vehicle (registration number, electric vehicle model, battery capacity, etc.), the credit/debit card to be used for payment of the extra fee for priority charging, and default values to be used to simplify the charging requests
- Charging requests with charging constraints such as priority/no priority, the latest finish time for the charging, the amount of energy requested, and the minimum SoC

The app backend is facilitating the integration with the CPO:

- Extended charge management functionality for the provision of information about charging demands to the smart energy management system.
- Billing and payment in case of priority charging (extra fee)
- Charge management system (legacy system)

When the CPs are installed, the EV users can connect and charge at any time, and stay connected as long as they want, also when they are not charging.

- The app is used to define the charging constraints and, if relevant, to change the constraints for an ongoing charging session
- The app will provide information about the charging fees for priority and flexible charging
- The EV user can monitor the charging by means of the app
- The app provides an overview of their charging history

If the user for any reason does not use the app (i.e., that the charging is initiated by a RFID tag and the app is not used), the EV will be charged with a minimum amount of electric current (8 A) for 6 hours.

The flexibility in the smart charging in the garage, is when the EV is charged depending on energy availability, greenness and price.

- This is the default charge option
- The required input data (requested amount of energy, latest finish time and minimum SoC) are provided via the App
- If the energy demand of all EVs charging in the garage cannot be fulfilled, the available energy is shared among the EVs. At least, the minimum SoC must be reached

There is also an option for priority charging, and the following principles are followed:

- The required charging constraints are provided via the App.

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

- If there is a lack of energy, the charging will be done prior to charging of EVs with no priority.
- If many users, requests priority charging at the same time, and there is not sufficient energy to all, the available energy is shared among these users.

4.1.2 Implementation of smart energy management measures in OSL.D1

The following hardware installations are done to facilitate the smart energy management:

- PV panels on the roof of the garage (capacity of 70 kWh, 300 W per panel)
- Stationary batteries for storage of energy (capacity of 50 kWh)
- Integration with the local energy grid

The software facilitating the energy management will:

- Monitor issues that may affect the energy availability and use (weather, RES production, stationary battery, charging demands with varying flexibility, heating cables, etc.)
- Predicted energy demands and availability (derived from monitored and historical data). Weather conditions may for example influence both the RES production and the energy demands
- Calculate and maintain a dynamic plan for optimal energy use, and control the use of energy from RES, and the use of the stationary battery capacity (charging and discharging) according to the plan
- Extended charge management (implemented by the app back end) will manage charging sessions according to the dynamic plan for optimal energy use. The charging at individual charge points are started and stopped, and the amount of energy transferred is be controlled according to the plan
- Software in connected devices (e.g. energy metres, PV panels, and stationary battery) will provide data. Some devices (e.g. the stationary battery) will also receive instructions regarding charging and discharging

PV panels are installed for local production of green energy, and the use of the energy from RES is optimised (e.g., storage vs immediate use) by the energy management system. The battery will support the storage of energy surplus from RES production (i.e., when it cannot be used).
The system is controlled by the following information:

- Information on the charging demand is managed for each CP. This is: Energy demand, latest finish time, minimum SoC, and the charging option (priority or not)
- Data on energy availability, use and production for the whole garage is managed. This includes energy needed for charging and heating cables as well as the energy available from the grid, local RES and stationary battery
- Optimal energy distribution among energy demanding activities, charging included, is dynamically calculated based on information on all energy demand, historical data, energy availability and production
- The charging of individual EVs, use or storage of energy from local RES, and the use of energy from stationary batteries are scheduled for optimal load balancing and optimal use of energy from RES
- The schedule is used to control the charging as well as other activities

4.1.3 Implementation of business aspect measures in OSL.D1

The software facilitating the implementation of the business models is the Charge management system of CPO handling the billing for charging in general. app is used by residents to provide input on the charging demand (priority or not and flexibility). Input on the debit/credit card is to be used for payment of fees for priority charging. When using "default" or flexible charging there is no extra fee. The fee is set to NOK 1.70/kWh. The billing is managed by the CPO, and the CPO will keep a share of the payment and transfer the rest to the housing cooperative as a payment for the energy used.

If users select priority charging, the price is set to 2.50 NOK/kWh, i.e. an extra fee of 0.80 NOK. The billing of the extra fee is managed by the app back end rewarding prosumer in ESN: Energy from PV panels replaces energy from the public grid and the energy from the PV panels may also be sold.

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

4.1.4 Implementation of charging measures in OSL.D2

The demo addresses how a private actor like a housing cooperative can share their charge points with the public. In the demo, the housing cooperative share four charge points that are located outdoor.

The software facilitating the charging are the same app as in D1. In addition to charging at private CPs, anybody can download, install and use the app for the 4 shared CPs. The app facilitates CP bookings, authentication of the users and authorisation for charging and payment. Functionality includes:

- Charge management system of CPO
- Calendar system supporting the booking of charging sessions
- Roaming platform supporting authentication and authorisation.
- App back end supporting roaming.

The CPs must be booked before they can be used, and booking is done via the ZET.Charge app at any time before the charging starts. The booking defines the time slot and the energy request. The latter is provided indirectly by indication of the current and the wanted state of charge (SoC). On arrival to the CP, the EV user must authenticate via the app and plug-in the EV. The EV must be plugged out before the end of the booked slot-time. The price for charging has been set to NOK 3.5/kWh. Blocking fee is set to NOK 12/hour (booking and not showing up). If the EV is not un-plugged at the end of the booked time slot, the charging is stopped, and a blocking fee of NOK 25/hour is charged. After charging session is finished the car must be unplugged (within 15 minutes) to avoid blocking fee.

The EMP will do the billing and get the payment from the EV user. When an EV user books a CP, a payment reservation on his/her credit card (via the App) is done for future payment to the EMP. The payment reservation will cover the costs in case of no show. If booked charging is initiated, billing is supported. Information (from CPO) on the connected time (time between plug in and plug out) and information (from EMP App) on the booked time slot is input to the billing. The EMP will transfer money to the CPO (according to the agreement between the CPO and the housing cooperative) and to the housing cooperative. In addition, the housing cooperative will pay a monthly fee to the CPO and the energy bill.

4.1.5 Measures implemented in OSL.D3

OSL.D3, is a part of the pilot and will collect data via sensors and meters installed in apartments and on hot water heaters in the building block. OSL.D3 was initially not a separate demonstrator but included in OSL.D1. Data collection from power consumptions in apartments and from hot water production was be used to simulate an ESN in combination with OSL.D1.

The data is collected via FutureHome sensors installed in apartments in building blocks, and Sodvin sensors collects data from hot water heater tanks. OSL.D3 is not a complete demonstrator, and it will not be evaluated since it is not related to e-mobility. OSL.D3 is just included to facilitate the access to data on energy use from apartments, and data was used in simulations.

4.1.6 Common measures implemented for the Oslo Demo

Information to, and feedback from users, are an important part of the project, and is an important part of evaluating the success of the project. To inform the residents and users of the measures taken in the Oslo pilot, several mechanisms for dissemination of relevant information were implemented. In parallel several mechanisms for collecting feedback were implemented:

- Information to the residents have been given to the users (residents) in at an information meeting (June 2021)
- There has also been sent out emails to users (and potential users)
- Several news articles have been published in Norwegian media (Teknisk Ukeblad and Dagens Næringsliv)
- The demo site was officially opened by the Governing Mayor of the City Government of Oslo in January 2020

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

- A YouTube video was created and put online to explain the GreenCharge project and its measures in Oslo

To collect feedback, several surveys have been carried out (Nov 2018, Des 2019-March 2020). If the residents had any questions, they could send email to project at greencharge@roverkollen.no, and app support was managed by partner ZET. It was planned to include a survey in the app, but due to the delayed start-up this was not implemented.

Table 6 below summarizes all the supporting common measures.

Table 6: Supporting common measures

Supporting activity (stage)	Target group(s)	Main objectives
Questionnaires (design)	Residents	• Get baseline data on the need and willingness among the residents to get charge points in the garage.
Workshops on demo content (design)	Local demo group (partners, technology providers, housing cooperative).	• Provide information. • Exchange of expectations. • Identify initial situation. • Defining scope of demonstrator.
Workshop on business model design; Business Model Innovation game (design)	Project partners involved in the demonstrator, Local Reference Group.	• Identifying the current business model and cost/revenue streams. • Explore innovative business model elements.
Meeting on business models (design)	Housing cooperative leader, project partners involved in the demonstrator.	• Agree on business models that will be implemented. • Agree on price models, reward and penalty mechanisms included.
Regular technical meetings (design/implementation)	Demo coordinator, technology providers, and (when needed) board of housing cooperative. Partners responsible for design/implementation.	• Clarify and agree on needed functionality. • Define need for technical installations (CP, infrastructure, PV, battery, etc.), what and who (responsibilities). • Solve problems and clarifications on dataflow, content, and responsibilities.
Meetings and telcos with the leader of the housing cooperative (design/implementation))	Leader of housing cooperative. Steering committee of housing cooperative.	• Information exchange. • Good relationship and mutual understanding. • Access to information on concerns. • Willingness to contribute to the research.
Email account as a communication channel towards residents (all stages)	Residents	• Provide email address to the residents for questions and feedback on the implementation phase and use of chargers (not about app – this is handled vis app support function)
Workshop on business models (implementation)	Local demo group (partners, housing cooperative).	• Defining business model and price models for charging solution in housing cooperative.
Workshop (telco) to agree on the business model and price model to be used (Implementation)	Housing cooperative EMP	• Prepare operation, billing and payment.
Information meetings (implementation)	Residents	• Willingness to buy private charge point and thereby increase the number of EVs.

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

<table>
<tr><th>Supporting activity (stage)</th><th>Target group(s)</th><th>Main objectives</th></tr>
<tr><td></td><td></td><td>• Willingness to use app to authenticate, provide data and start charging session.</td></tr>
<tr><td>Questionnaire – repeating the first with some extra questions (implementation)</td><td>Residents</td><td rowspan="2">• Get more baseline data
• Check if the residents' wishes and needs has changed.
• Collect feedback on the installed charge points and willingness to offer flexibility / pay for priority.</td></tr>
<tr><td>Interviews (implementation)</td><td>Residents</td></tr>
<tr><td>Launch event with media (implementation)</td><td>Public</td><td>• Promote the project and demonstrator for the public.
• Meeting with reference group.</td></tr>
<tr><td>Information letters (implementation)</td><td>Residents</td><td>• Summarize results from questionnaire.
• Provide a written thanks for participation.
• Increased acceptance and awareness.
• Prepare launch of app and demo.</td></tr>
<tr><td>Information meeting for app launch (implementation/operation)</td><td>Residents</td><td>• Support for use and setup of app for charging.</td></tr>
<tr><td>Focus group</td><td>All partners involved in demo</td><td>• Input to process evaluation.</td></tr>
<tr><td>Questionnaire (operation)</td><td>Residents</td><td>• Receive feedback on first test of EMS and use of app (planned).</td></tr>
<tr><td>Weekly meetings addressing implementation and roll out barriers.</td><td>All partners involved in the demo implementation.</td><td>• Identify (potential) problems.
• Agree on actions and responsibilities.
• Follow up actions.</td></tr>
</table>

4.2 Indicators relevant for the Oslo demos

The table below presents the indicators for the OSL.D1 and OSL.D2 as defined in deliverable D5.1/D6.1.

Table 7: Indicators for OSL.D1 and OSL.D2

<table>
<tr><th>Demo</th><th>Indicator</th></tr>
<tr><td rowspan="10">D1</td><td>Number of EVs</td></tr>
<tr><td>Number of charging points</td></tr>
<tr><td>Utilization of charging points</td></tr>
<tr><td>Charging availability</td></tr>
<tr><td>CO2 emissions</td></tr>
<tr><td>Charging flexibility</td></tr>
<tr><td>Energy mix</td></tr>
<tr><td>Peak to average ratio</td></tr>
<tr><td>Average operating costs for charging infrastructure</td></tr>
<tr><td>Capital investment costs</td></tr>
</table>

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

Demo	Indicator
	Average operation revenue
	Savings
	Awareness level
	Acceptance level
D2	Number of EVs
	Number of charging points
	Utilization of charging points
	Charging availability
	Energy mix
	Average operating costs for charging infrastructure
	Capital investment costs
	Average operation revenue
	CO2 emissions
	Awareness level
	Acceptance level

Example of indicator of number of charging points (installed and activated) for OSL.D1 is shown in the figure below.

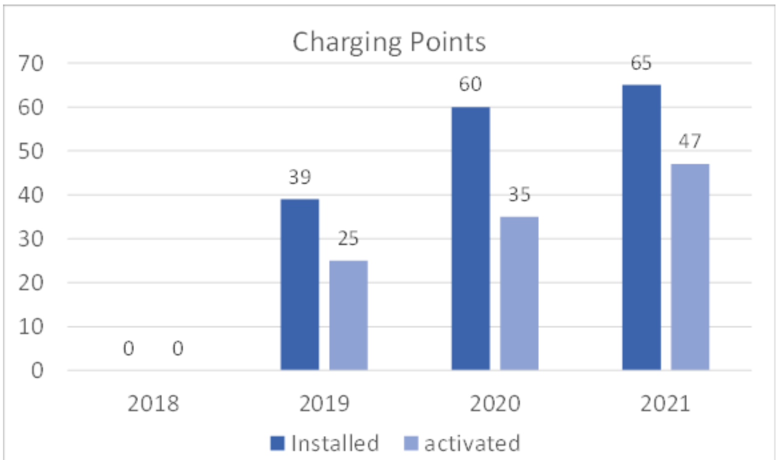

Figure 8 Installed and activated charging points (CP) in OSL.D1

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

5 Research data collection

5.1 Implementation in manual and automatic mode

For the Oslo pilot both static data with information on equipment and systems, and log entries with logged data was collected. The static data include information of device models and individual devices. For these files technical data have been collected and the files created manually. The log-file data include both static metadata and logged values. The metadata have been created manually and/or added to the log files with a script.

Table 8: Data collection overview

File type	Data file	D1	D2	D3	Comment
Device models	Heating/Cooling device models	-	-	x	Created manually from technical description and data sheets for installed system from FutureHome and Sodvin
	PV panel models	x	-	-	Created manually from technical description and data sheets for installed system from OneCo
	Battery models	x	-	-	Created manually from technical description and data sheets for installed system OneCo
	Inverter models	x	-	-	Created manually from technical description and data sheets for installed system from OneCo
	Sensor models	-	-	x	Created manually from technical description for installed system from FutureHome and Sodvin
	EV models	x	x	-	For D1: created manually based on information on EV types collected from Elbilforeningen EV models included in common database for all pilots in GC
Individual devices	Individual software system	x	x	x	D1: created manually. Software by ESMART and ZET D2: created manually. Software by ZET and HUBJ D3: created manually. Software by FutureHome and Sodvin

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	Location	x	x	x	Created manually
	Individual Heating/ Cooling devices	-	-	x	Created manually from technical description and data sheets for installed system from FutureHome and Sodvin
	Individual Solar plants	x	-	-	Created manually from technical description and data sheets for installed system from OneCo
	Individual Stationary Batteries	x	-	-	Created manually from technical description and data sheets for installed system from OneCo
	Individual Sensors	-	-	X	Created manually from technical description for installed system from FutureHome and Sodvin
	Individual EVs	x	x	-	Collected automatically through ZET.Charge app Will be collected by ZET by information given by user in app for OSL.D1 and OSL.D2
	Individual Charge points	x	x	-	Created manually CPIDs received from FORTUM. CPIDs anonymized with UUID and uploaded to SFTP-server
	Individual energy metres	x	x	x	Created manually
	Individual price lists	x	x	x	Created manually Common price lists for all GC pilots to be created by PNO
	Individual tariff scheme	x	x	x	Created manually Common price lists for all GC pilots to be created by PNO
Logfiles	Metadata on reservation/booking events	x	x	-	The process for data collection and provisioning are in place. Need users that charges at the outdoor chargers. Will be uploaded by ZET.
	EV charging/ discharging sessions	x	x	-	Uploaded to SFTP-server by ZET.
	Heating/cooling sessions	-	-	x	Two types of logfile-sets Logfiles for apartments: SINTEF extracts logged energy use for heating devices from FutureHome system.

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					Logfiles for DHW[5]: Sodvin upload logged data from the DHW tanks once a month
	Washing machine/dish washer sessions	-	-	-	Will not be collected
	Solar plant sessions	x	-	-	Collected automatically by ESMART system and uploaded manually Data for produced and accumulated energy in kWh/15 min.
	Battery sessions	x	-	-	Collected automatically by ESMART system and uploaded manually
	Metadata on payment information	x	x	-	The process for data collection and provisioning are in place. Need users that charges at the outdoor chargers. Will be uploaded by ZET.
	Energy import and export	x	-	-	Collected automatically by ESMART system and uploaded manually
	Average grid mix in public grid	x	-	-	Yearly values from NVE. SINTEF has provided data
	Variable energy cost in local grid and public grid	x	-	-	ESMART uploads data
	Predicted weather data	x	-	-	Collected automatically Predicted and collected by ESMART system for D1. Uploaded manually
	Measured weather data	x	-	-	Collected automatically by ESMART system and uploaded manually
	Sensors	-	-	x	Logfiles for apartments: SINTEF extracts logged temperatures for heating devices from FutureHome system

5.2 Results of data collection

Despite several challenges with data collection, a lot of data has been generated and collected (see Appendix A.1 for examples of files generated). Data is collected in accordance with the "Research Data" document provided in deliverable *D5.6 Open Research data* as part of the project's work package 5 (WP5).

Data on EV models were the most challenging to collect, since required input from the EV owners. Make and model of EV are known to owners, technical data like battery capacity are not always known. Also, some of the EV owners have changed car during the project period, without informing the project. By the end of the project, we have information on 46 EVs.

The logfiles comprises of both static data and logged values. Some logged values are collected automatically, and then upload manually to the file server, but many logfiles was created manually. The uploads to the fileserver were all done manually.

[5] DHW = Domestic Hot Water

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Metadata on reservation/booking events and EV charging/discharging sessions are data uploaded by ZET. The data from charging/discharging sessions have been dependent of a working app and booked charging session in the garage or outside. Since the start-up of the demo was delayed the only "real" data available are from test user. These data were created during development of the App. The number "EV charging and discharging session" files are 96.

The sensor data files from OSL.D3 are data collected manually, with software from FutureHome and Sodvin. Sodvin provides the data by manually uploading them. These data are not dependent on operations of neither OSL.D1 or OSL.D2, and have therefore been collected since March 2021.

Weather data (both measured and predicted) are supplied by ESMART. These data are uploaded regularly. Initial errors in data structure and filenames were corrected. Data were collected in 2020-2021.

The average grid mix are data to be collected from NVE (Noregs vassdrags- og energidirektorat) by SINTEF. Its yearly statistics of energy mix used. The energy is a mix of renewable energy, nuclear power and fossil fuels.

Energy prices can be found at Nordpool data portal, and data for "variable energy cost" is collected from this portal by ESMART. The data had to be downloaded manually from Nordpool and uploaded to the file server.

5.3 Challenges

To get the demos up and running, enabling research data collection, was more challenging than expected. The challenges can be split in two:

1. Challenges directly related to collection of research data
2. Challenges related to operate the pilot to generate research data

The challenges are summarized in Table 9 below.

Table 9: Challenges related to data collection

What	Description
1. Challenges directly related to collection of research data	
Common data structure of research data: - File format - File format for simulations	A common structure for all research data files have been created in the project, for both static data and for log-files. Several reviews and updates on format of the research data have been implemented. Data had to be altered manually later. The final format of research data files is described in deliverable *D5.6 Open research data.*
Data provider not aware of data structure or responsibilities.	Changes in staff at data provider has caused delays. New staff has been unaware of responsibilities to deliver data or unaware of file structure
Delayed operative pilot and demonstrators.	The demonstrators in the Oslo pilot were delayed. The delays and causes are described in section *3.2 Operation of the demonstrators*. A shorter data collection period and test period for smart management, business models etc. This might reduce the total quality of the collected data as it has fewer representative months. Test period should have been running for at least one year
Corona	Due to Corona and more use of home office and less leisure activities – change in driving habits.

What	Description
	Collected baseline data not representative for a normal driving pattern, or according to answers in previous surveys.
Data providers not delivering data	Data providers postponing the delivery of data. This was both due to integration issues and uncertain division of responsibilities (especially between partners and sub-suppliers). Data missing on servers. Time consuming to figure out where data is located and getting new delivery.
2. Challenges related to operate pilot to generate research data	
Change of partners / roles in	New partner needed to be found in order to implement the planned measures. ZET replaced FORTUM on several tasks – from February 2020. This caused delay since it increased the need for new interaction, creating new APIs and onboarding in systems that were not in the original plan. Change of contact/responsible person within the different partners lead to delays which again lead to challenges in generating data.
Few users of ZET.Charge.	The ZET.Charge app was launched to all the owners of a CP in the garage at Røverkollen (OSL.D1) on 16th March 2021. A total of 25 persons tried the app (out of 42 active CPs), but since the demo was not operational at that time, no real data was produced. Lack of users means that data related to charging habits and user needs before the smart managements was enabled is missing.
Communication with CP	Installed CPs in the garage was not ready for receiving signals from CMS. Several changes in the backend system had to be done. Delayed start-up of demo.
Software	APIs not open. Need for creating new APIs for data transfer and communication. This also applies to the installed hardware: CPs, batteries, app.
Onboarding	Difficult to get all the partners working together at the same time with the same issue. Onboarding takes time resulting in delay in testing and start-up. Errors in App, software integration, and firmware in the charging points are time consuming to identify and to solve. Debugging required onsite testing. This was done too late in project, resulting in delayed start-up.
Contracts between partners	The contract regulating payment (involving FORTUM and ZET) was delayed. Several iterations were needed, with the involvement of the respective partner's legal department. This delayed the activation of the demo.

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6 Lessons learned

This chapter summarizes the lessons learned from the Oslo pilot, and can be used to develop guidelines for further work related supporting smart energy management when charging EVs. The smart energy management supports more cost-efficient deployment and operation of charging infrastructure, and leverages new viable business models for the required infrastructure towards wide-scale adaption of EVs in residence areas or neighbourhoods.

- Integration of NEMS involves a plethora of stakeholders from different organisations. Having a common online platform to track the software development activities, instead of scheduled weekly (or bi-weekly calls), is expected to be more effectively in tracking the actual progress of development and integration activities. This is even more important when the APIs to realise a fully functional NEMS are not yet standardised.
- To a large degree the installed technologies in the pilot are commercially off-the-shelf products, when treated on their own, but cannot be considered "smart-ready". Integration is time consuming due to missing, non-open, or under-documented APIs, and the implementation of a working demonstrator requires tight cooperation between several different partners and companies.
- It is difficult to create a test environment that is realistic enough to support integration testing. Several errors were not detected when testing the app in the test environment, only discovered when doing on-site testing with app and an actual EV at the charging point.
- It is essential to ensure tight cooperation and open dialogue with the problem owner (in this case the housing cooperative). The board at Røverkollen housing cooperative have during implementation provide invaluable support to the residents at the housing cooperative owning EVs. The residents have been dependent on support from the board (which is very competent).
- Even if a lot of issues have been sorted out by the board at Røverkollen, other issues was discovered that needed to be fixed by one of the project's partners. It has not always been clear to the board whom they should address issues to. A single point of contact (i.e. an integrator), with sufficient technical expertise, should have been established towards the board at the start of the implementation phase.

From a research viewpoint, there have been several challenges related to data collecting. Some challenges have been of technical nature, but the most common challenges were getting the relevant data provider to deliver data as planned and agreed, and ensuring that the data adheres to the correct file structure and naming conventions. During the course of the project there have also been changes or revisions in the specifications related to datafiles and structure (ref. deliverable *D5.6 Open research data*). This has resulted in the need to manually change already collected data. Collecting data manually can be challenging. Manual collection, delivery and possibly correction of data, results in errors in data structures, filenames and delays in delivery.

Mobility planning in the city of Oslo consists of different sub-strategies and different mobility plans. This means that the city of Oslo does not have any SUMP or an overall mobility strategy. Knowledge from this project will serve on different levels within mobility planning. Strategies worth mentioning are strategy for route selection for charging infrastructure and Oslo’s climate strategy 2030.

Energy smart neighborhoods and eRoaming, contributes to better understanding of necessary measures to ensure electrification of the city and accessibility of smart solutions. Especially in view of the increased demand and use of electric vehicles.

Around 70% of citizens of Oslo live in buildings with an older infrastructure, that do not have the capacity to secure electricity to charge EV. The Oslo municipality will use results from GreenCharge, and especially the Oslo pilot, as a guide for housing associations in choosing the right solutions for charging infrastructure, ensuring proper resource utilization. Results can also contribute to properly focus on working with common infrastructure for charging points that are accessible to anyone, anywhere. By combining ESN with eRoaming, we can form a holistic understanding of the entire electrical infrastructure in Oslo.

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7 Conclusions and Future Work

During the project, 65 parking spaces were equipped with charging points and integrated with a NEMS, and four publicly available outdoor parking spots were equipped with bookable charging opportunities.

As described in this deliverable, establishing the required infrastructure and integrate the required sub-systems to implement smart energy management to support of user-friendly and attractive charging solutions is both challenging and time consuming. These cost reductions are both related to reduced investment costs due to less need for costly grid upgrades and reduced operational costs due to optimized utilisation of local renewable energy.

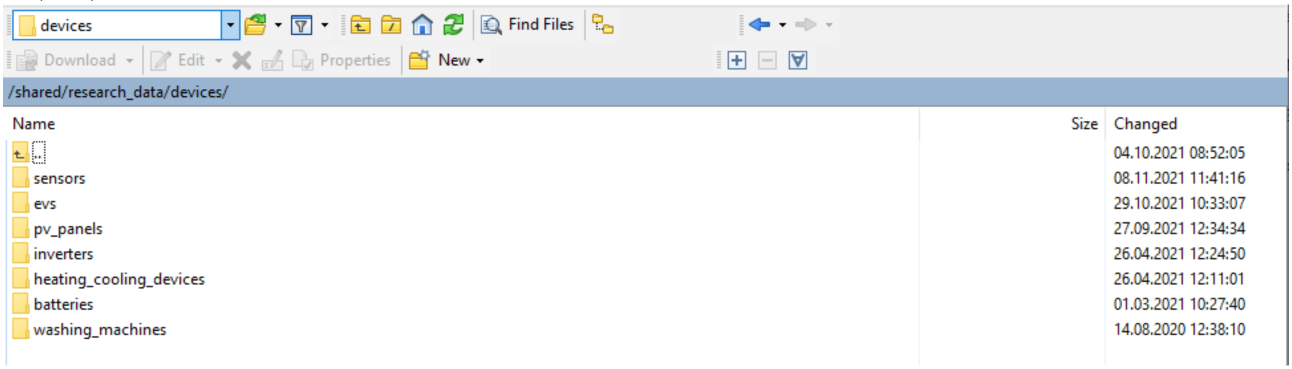
To reduce the challenge, and associated development costs, of implementing similar systems as those piloted at Røverkollen housing cooperative, there is a need to accelerate the standardization activities related to the interfaces and APIs between different sub-systems. This includes standardization of interfaces between NEMS, CMS, user friendly charging apps and associated roaming services. In addition, this means easily accessible energy consumption data from battery management systems, domestic hot water heater tanks etc.

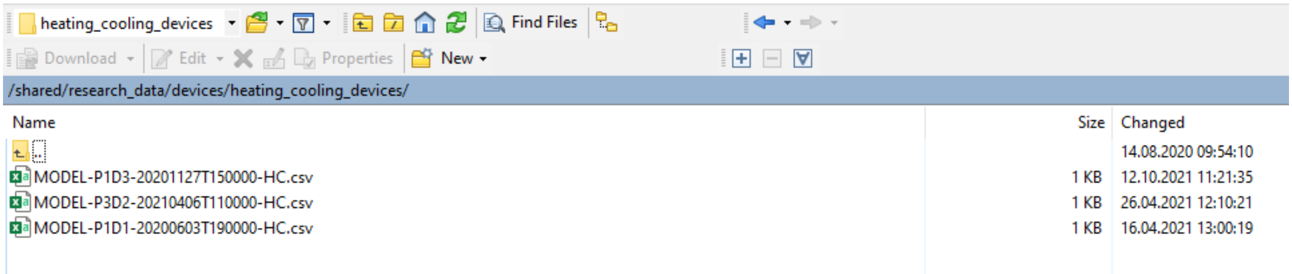
The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020) under grant agreement n° 769016.

A Appendix A - Examples of directories and datafiles on SFTP server.

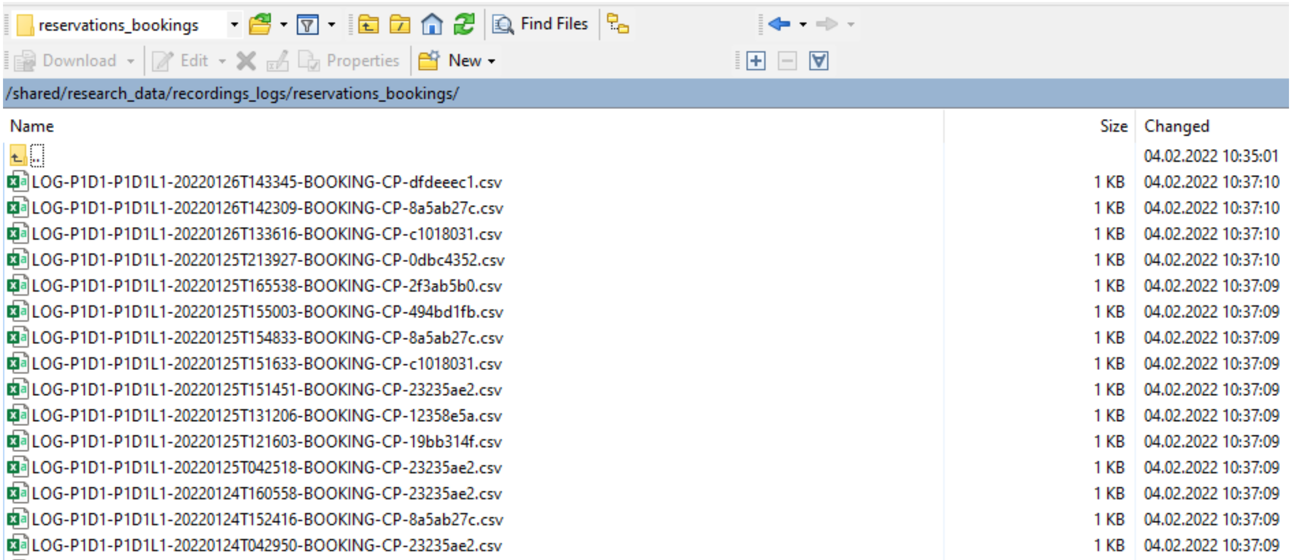
This appendix provides examples of directories and datafiles uploaded to the SFTP server.

D1, D2, D3: Device model data:



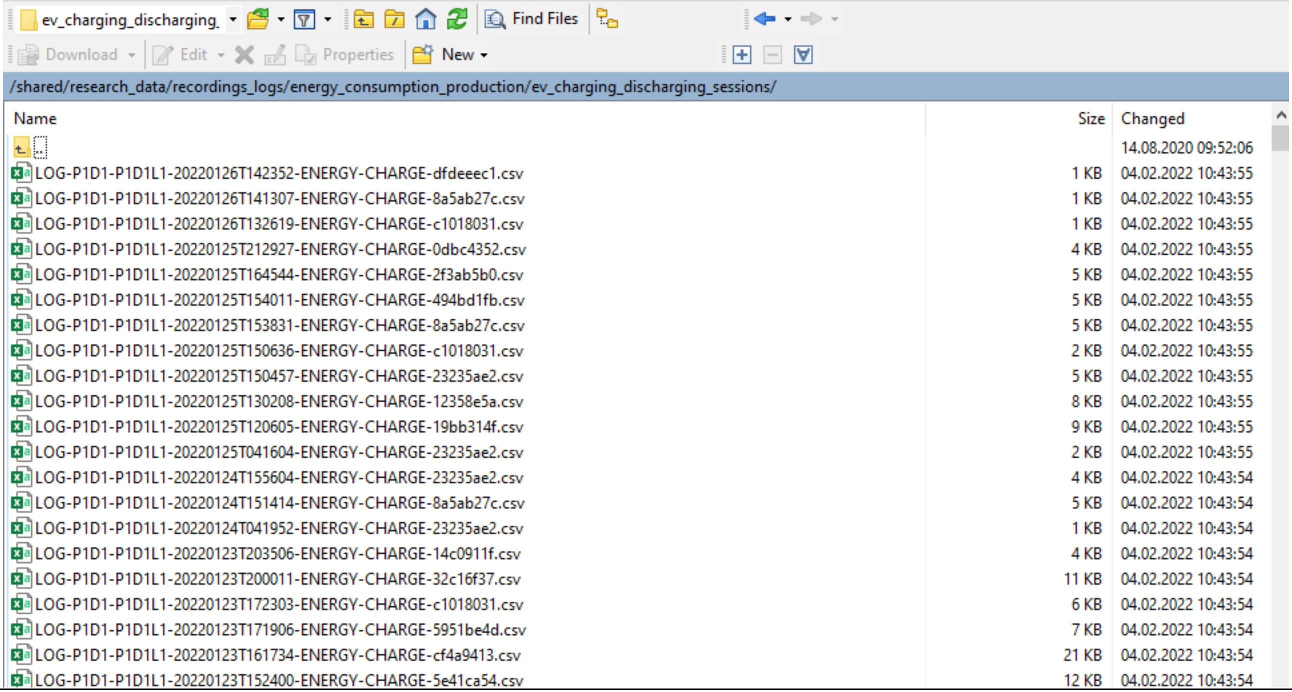


D1: Reservation- booking events:



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

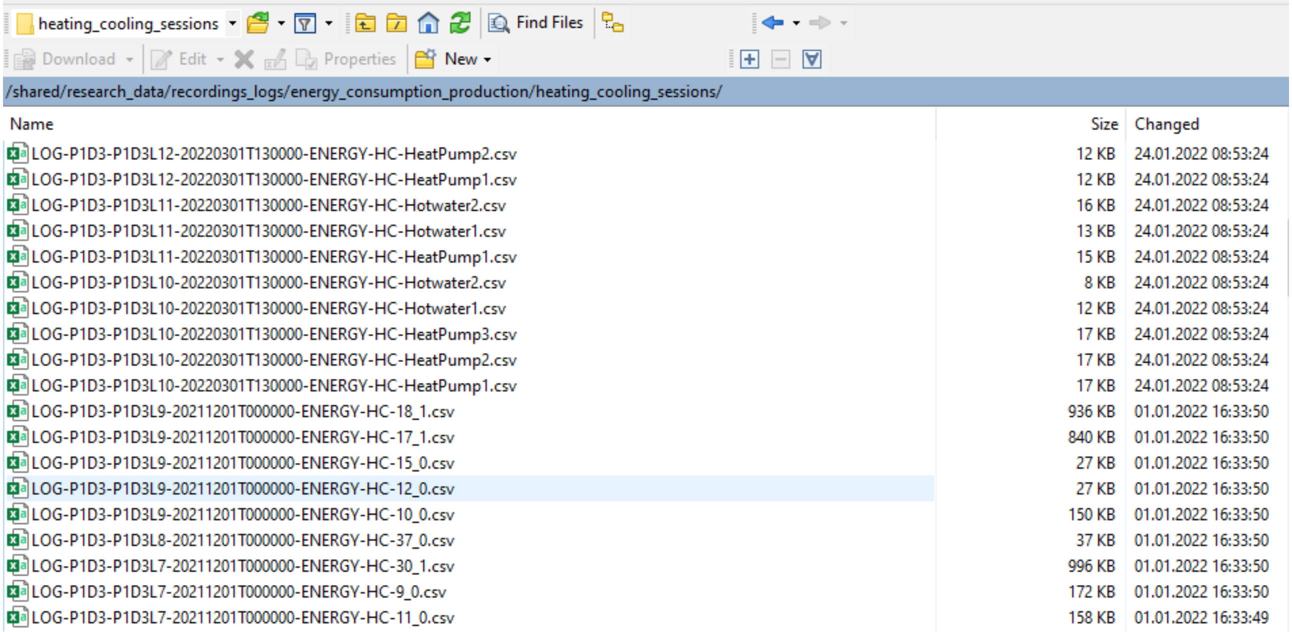
D1: EV charging-discharging sessions:



/shared/research_data/recordings_logs/energy_consumption_production/ev_charging_discharging_sessions/

Name	Size	Changed
..		14.08.2020 09:52:06
LOG-P1D1-P1D1L1-20220126T142352-ENERGY-CHARGE-dfdeeec1.csv	1 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220126T141307-ENERGY-CHARGE-8a5ab27c.csv	1 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220126T132619-ENERGY-CHARGE-c1018031.csv	1 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T212927-ENERGY-CHARGE-0dbc4352.csv	4 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T164544-ENERGY-CHARGE-2f3ab5b0.csv	5 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T154011-ENERGY-CHARGE-494bd1fb.csv	5 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T153831-ENERGY-CHARGE-8a5ab27c.csv	5 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T150636-ENERGY-CHARGE-c1018031.csv	2 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T150457-ENERGY-CHARGE-23235ae2.csv	5 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T130208-ENERGY-CHARGE-12358e5a.csv	8 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T120605-ENERGY-CHARGE-19bb314f.csv	9 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220125T041604-ENERGY-CHARGE-23235ae2.csv	2 KB	04.02.2022 10:43:55
LOG-P1D1-P1D1L1-20220124T155604-ENERGY-CHARGE-23235ae2.csv	4 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220124T151414-ENERGY-CHARGE-8a5ab27c.csv	5 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220124T041952-ENERGY-CHARGE-23235ae2.csv	1 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220123T203506-ENERGY-CHARGE-14c0911f.csv	4 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220123T200011-ENERGY-CHARGE-32c16f37.csv	11 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220123T172303-ENERGY-CHARGE-c1018031.csv	6 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220123T171906-ENERGY-CHARGE-5951be4d.csv	7 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220123T161734-ENERGY-CHARGE-cf4a9413.csv	21 KB	04.02.2022 10:43:54
LOG-P1D1-P1D1L1-20220123T152400-ENERGY-CHARGE-5e41ca54.csv	12 KB	04.02.2022 10:43:54

D3: sensor-datafiles: heating-cooling sessions

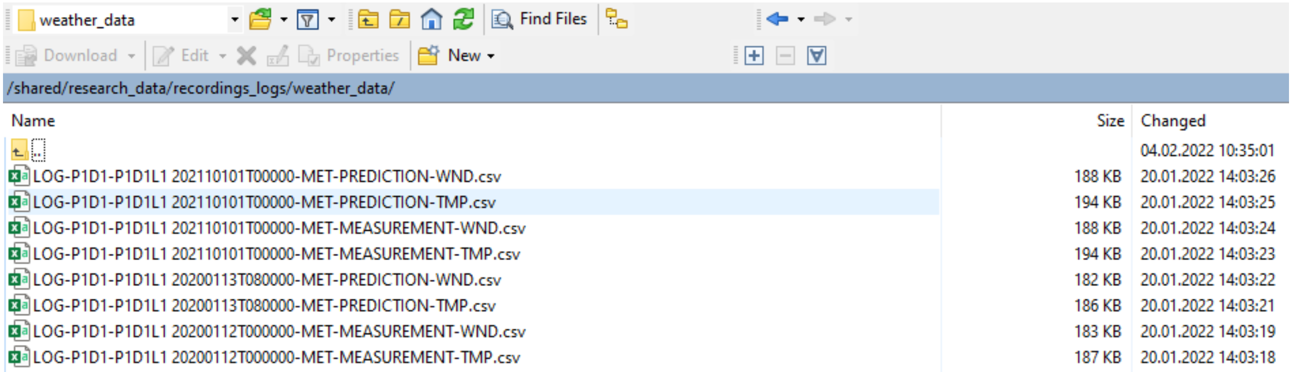


/shared/research_data/recordings_logs/energy_consumption_production/heating_cooling_sessions/

Name	Size	Changed
LOG-P1D3-P1D3L12-20220301T130000-ENERGY-HC-HeatPump2.csv	12 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L12-20220301T130000-ENERGY-HC-HeatPump1.csv	12 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L11-20220301T130000-ENERGY-HC-Hotwater2.csv	16 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L11-20220301T130000-ENERGY-HC-Hotwater1.csv	13 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L11-20220301T130000-ENERGY-HC-HeatPump1.csv	15 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L10-20220301T130000-ENERGY-HC-Hotwater2.csv	8 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L10-20220301T130000-ENERGY-HC-Hotwater1.csv	12 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L10-20220301T130000-ENERGY-HC-HeatPump3.csv	17 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L10-20220301T130000-ENERGY-HC-HeatPump2.csv	17 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L10-20220301T130000-ENERGY-HC-HeatPump1.csv	17 KB	24.01.2022 08:53:24
LOG-P1D3-P1D3L9-20211201T000000-ENERGY-HC-18_1.csv	936 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L9-20211201T000000-ENERGY-HC-17_1.csv	840 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L9-20211201T000000-ENERGY-HC-15_0.csv	27 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L9-20211201T000000-ENERGY-HC-12_0.csv	27 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L9-20211201T000000-ENERGY-HC-10_0.csv	150 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L8-20211201T000000-ENERGY-HC-37_0.csv	37 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L7-20211201T000000-ENERGY-HC-30_1.csv	996 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L7-20211201T000000-ENERGY-HC-9_0.csv	172 KB	01.01.2022 16:33:50
LOG-P1D3-P1D3L7-20211201T000000-ENERGY-HC-11_0.csv	158 KB	01.01.2022 16:33:49

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

Weather data:



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