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

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

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GreenCharge Project Deliverable: D4.2

Final Architecture Design and Interoperability Specification

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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 is the final version of the GreenCharge reference architecture. It supports the understanding of the GreenCharge concept and serves as a blueprint for planning and construction of systems and system components that together realise the concept. The modified and/or or added responsibilities and collaboration patterns necessary to support the concept are defined.

The GreenCharge concept is that electric vehicles, charge management and local energy management work together to facilitate a transport system running on green energy. Users of electric vehicles get charging support, and peaks in the power grid and grid investments are avoided through a balance of power. When many vehicles are plugged into the grid around the same time (e.g., on returning home from work), the energy management balances demand with available supplies. Supplies from local renewable energy sources and batteries in connected vehicles not in use may also be utilised. The concept also includes viable business and price models rewarding charging behaviour contributing to peak reductions.

The architecture description provided in this deliverable uses terms and concepts from the standard ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description (ISO/IEC/IEEE 2011), and the deliverable is also structured according to recommendations from this standard.

The architecture description identifies the **stakeholder** types playing a role in the realisation of the GreenCharge concept and their motivations and concerns. The main stakeholder types are:

- **EV User**. An electric vehicle (EV) User wants predictable access to and high availability of charge points, low mobility costs, and assistance for smart charging.
- **eMobility Provider (EMP).** The EMP provides charging services to EV Users.
- **Charge Point Operator (CPO).** The CPO operates the charging infrastructure.
- **Roaming Operator.** The Roaming Operator facilitates the roaming of charging services between roaming endpoints (operated by EMPs and/or CPOs).
- **Local Energy Manager (LEM).** The LEM facilitate optimal use of energy, considering the energy availability, local energy production, energy demands, and energy storage.

Different **architecture views** address different perspectives of the **system of interest** which is the integration of systems/system components that facilitate a realisation of the GreenCharge concept:

- The **context view** provides a use case model describing the functionality needed by the stakeholders. A use case to service mapping model links the use cases to logical system components (services). An environment model defines the environment in which the solution will operate.
- The **requirement view** defines generic and principal requirements for the realisation of the GreenCharge concept based on the overall concerns and functionality needed by the stakeholders.
- The **component view** addresses how the logical system components collaborate and interact. An information model defines the information exchanged, a system component and interface model identify interfaces and messages, and a system collaboration model defines the interactions.
- The **deployment view provides** examples of the view from the GreenCharge pilots.

The main innovations addressed by the reference architecture description are:

- Public sharing of extended charge point (CP) information, available time slots included.
- Advance booking of charge points. They can be booked several hours or days in advance.
- Charging requests with energy demand and flexibility details, enabling smart energy management.
- Smart charge planning support, facilitating the above innovations.
- Charge planning as an integrated part of EV fleet management, for better resource utilisation.
- V2G support with use of vehicle batteries in local energy management.
- Integration of charge management in local energy management for smart and green charging.
- Price models promoting desired behaviour, though economic rewarding and penalties.

Recommendations regarding standardisation needed to realise the GreenCharge concept are also provided with references to the relevant parts of the reference architecture.

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List of Abbreviations

Table 0-1: List of abbreviations

Abbreviation	Explanation
ARCADE	Model-based Architecture Framework for Information Integration Abstraction used in the architectural work in GreenCharge. See http://arcade-framework.org/assets/documents/ARCADE-Handbook.pdf
CP	Charge Point
CPO	Charge Point Operator
CS	Charge Station
DSO	Distribution System Operator – responsible for operating and maintaining the electricity distribution grid.
EMP	E-Mobility Provider
ESN	Energy Smart Neighbourhood
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment. This delivers electric energy through a charge point, which can charge one vehicle at a time and may have one or several connectors (outlets or plugs).
ICT	Information and Communication Technology
KPI	Key Performance Indicator. KPIs are important indicators to understand the impact of a measures. They are described with definition, context, units and measurement methods.
LEV	Light Electric Vehicle. LEVs are EVs with 2 or 4 wheels powered by a battery, fuel cell, or hybrid-powered, and generally weighing less than 100 kilograms.
LEM	Local Energy Manager
MaaS	Mobility as a Service
RES	Renewable Energy Source. *Further explanation provided in "Definitions" below – list of terms related to Energy Management and eMobility".*
SUMP	Sustainable Urban Mobility Plan
SoC	State of Charge.
TSO	Transmission System Operator – responsible for operating and maintaining the electricity grid providing energy to consumers.
UML	Unified Modelling Language
V2G	Vehicle to Grid. This means to use the energy stored in the batteries of electric vehicles connected for charging to provide energy to the grid in peak load situations.
WP	Workpackage

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List of Definitions

This document makes use of some terminology that may be new to some readers. The table below is primarily intended as a source of ***reference*** for terms related to energy management and eMobility so that you can look up terms that you may find unfamiliar. Hopefully a quick scan of the definitions might work as an express "tutorial" for you on the topic. Terms and concepts related to the architectural work are provided in Annex A.

Table 0-1 List of definitions

Definition	Explanation
Charge management	The charge management is done by an ICT system supporting the operation of charging facilities, taking care of access control (to charging posts), control of the charging process (through communication with the in-vehicle charging and battery management system, booking and other business-related tasks necessary to the operation of a charge service. In GreenCharge it will also be responsible for the communication with local energy management about the coordination of energy demand of the charging facility with other demand in the neighbourhood and local production within the neighbourhood.
Energy mix	The distribution among different categories of electric energy sources involved in supplying a given amount of electric energy. Relevant categories include local renewable, grid renewable, local fossil, grid fossil etc. It is often given as a percentage for each category (altogether amounting to 100%) but can also be the fraction of a particular category, for example the fraction of renewables (the green mix).
Energy demand flexibility	Energy demand flexibility means to which extent a predicted energy demand can be shifted in time or power. For example if you start a dishwasher or washing machine in the morning, you may not need the clean dishes until you return from work in the evening, the water boiler need not be as hot in periods of low demand for hot water, so the power can be temporarily reduced or switched off, or when an electric vehicle is connected for charging in the afternoon, it may not be needed until the next morning. The flexibility is given as a time window within which the demand must be satisfied, together with constraints on the needed power as a function of time. GreenCharge has a particular focus on leveraging the demand flexibility of charging electric vehicles.
Energy flexibility	Energy flexibility is the amount of energy that for a certain period is available but not planned used. This may also include energy available from V2G (the V2G flexibility). This also depends on Energy demand flexibility.
Fleet management	The operation of a fleet of vehicles owned by a business and used to operate that business, for example the taxies of a taxi company, the delivery cars of a parcel delivery service company, or the cars of a car rental business. ICT systems offer a wide variety of functionality supporting tasks related to fleet management, such as vehicle tracking, mechanical diagnostics, maintenance planning, and when dealing with electric vehicles, also charge planning and booking.
Flexible charging	The charging can be done at any time before a deadline. In such cases, the charging can be distributed over time and adapted to the availability of energy and transfer capacity according to pre-defined rules (e.g., that the use of green energy should be prioritised).

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Definition	Explanation
GreenCharge concept	The concept is derived from the DoA and includes cross sectorial collaboration involving business actors and supporting technical systems of both the energy supply, transport and building sectors. Electric vehicles, charge management and local energy management work together to facilitate a transport system running on green energy. • Users of electric vehicles get planning and charging support. • Peaks in the power grid and huge grid investments are avoided through a balance of power. When many vehicles are plugged into the grid around the same time (e.g., on returning home from work), the local energy management balances demand with available supplies. Supplies from local renewable energy sources and the batteries of connected vehicles not in use may also be included. • Roaming services are provided for seamless access to the above across different charge point operators. • Viable business and price models reward charging behaviour contributing to peak reductions.
In-vehicle system	ICT systems embedded in a vehicle, for example the embedded charger and BMS. These systems need to communicate with charge management systems, driver assistance systems, and fleet management systems to implement the GreenCharge charging infrastructure.
Local energy management	The local energy management may be accomplished by a hierarchy of local energy management systems. The top level may be the management of a neighbourhood with many buildings. Different subsets of the neighbourhood may have their own local energy management. A local energy management system may manage local renewable energy sources (RES) and local energy storages. The latter may also be electric vehicle batteries (in case of V2G). The energy use is planned according to optimisation criteria, and energy demanding devices/activities are controlled to reduce the burden on both the local grid and the electricity distribution network and to minimize the power bill. The optimisation is done 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 distribution network, 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 them. In GreenCharge, there is a focus on leveraging the demand flexibility and storage capacity of charging electric vehicles, how this will reduce the need for stationary batteries, and increase the use of local RES to charge the increasing fleet of electric vehicles.
Local energy production	Energy produced inside a defined collection of one or more energy consumers and/or prosumers. If there are only consumers, the local energy production will always be zero.
Local RES	Local energy production by means of RES.
Public grid management system	A collection of systems used by the electric energy retailers and DSOs to operate a stable electric energy supply service and support their business.

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Definition	Explanation
Renewable Energy Source	This is a category of energy sources which does not involve the burning of fossil fuels as part of the energy production process. The most popular RES are photovoltaic panels, windmills and hydroelectric power plants. Typically, the carbon footprint of RES (caused by the building, operation and maintenance of the production facilities) lies in the area of 10 – 50 g CO2 equivalents per kWh, while for fossil energy sources like natural gas, oil and coal the carbon footprint lies in the area of 500 – 800 g CO2 equivalents per kWh. Nuclear power is not commonly counted as a RES, since the energy production process does consume a fuel and does produce a problematic waste (radioactive material). However, its carbon footprint is in the lower end of the RES range.
Self-consumption	The self-consumption (of a household or a neighbourhood or another group of energy consumers and prosumers) refers to the locally produced solar energy which is consumed locally. It is normally given as a percentage computed as the fraction of the locally produced energy consumed locally.
State of charge	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 electric vehicles has an instrument on the dashboard showing the SoC.
V2G flexibility	The flexibility provided by the electric vehicle user when he/she allows the use of the battery of the electric vehicle as an energy source regarding to when and how much energy stored in the battery can be used.

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1 About this Deliverable

This deliverable defines the final version of the GreenCharge reference architecture description and provides generic and holistic specifications for ICT solutions for smart and green charging. The intention is to capture the knowledge gained during the project and to serve as a blueprint for realisations of the **GreenCharge concept**.

The GreenCharge concept is derived from the DoA and includes cross sectorial collaboration involving business actors and supporting technical systems of both the energy supply, transport and building sectors. Electric vehicles, charge management and local energy management work together to facilitate a transport system running on green energy.

- Users of electric vehicles get planning and charging support.
- Peaks in the power grid and huge grid investments are avoided through a balance of power. When many vehicles are plugged into the grid around the same time (e.g., on returning home from work), the local energy management balances demand with available supplies. Supplies from local renewable energy sources and the batteries of connected vehicles not in use may also be included.
- Roaming services are provided for seamless access to the above across different charge point operators.
- Viable business and price models reward charging behaviour contributing to peak reductions.

1.1 Why would I want to read this deliverable?

The reference architecture description supports the planning, specification and implementation of solutions and services for smart and green charging. It contributes to a common understanding of

- What smart and green charging is and how smart and green charging fits into a wider context
- The different stakeholder types with a role in smart and green charging and their concerns
- The use cases and requirements to be supported by solutions for smart and green charging
- The information to be exchanged and the interfaces used to exchange the information
- The collaboration and interactions needed between different systems and system components

The deliverable also provides examples on how the architecture description is deployed in the GreenCharge pilots.

Recommendations are also provided with respect to future standardisation with references to the detailed specifications in the architecture that can be of relevance with respect to standardisations.

1.2 Intended readership/users

The main target group for this deliverable is readers with technical knowledge and knowledge in software engineering who plan to design and implement or are implementing solutions for smart and green charging. These readers can use the specifications provided as input to their software engineering processes. Parts of the deliverable may however also be of interest to other stakeholders, e.g., stakeholders aiming for a deeper insight into smart and green eMobility and possible solutions.

As illustrated in Figure 1, the deliverable has an introduction with two chapters. Chapter 1 is about the deliverable and Chapter 2 describes the approach and purpose with reference to the architecture description. The actual architecture description has two parts. Chapter 3 and 4 address the scope of the System of Interest and the stakeholders and their concerns. Chapter 6, 7, 8 and 8 describes the relevant viewpoints. The closure of the deliverable includes recommendations regarding standardisation in Chapter 10 and a conclusion in Chapter 11. The content is categorised according to the degree of technical competence we assume is needed by the readers (see legend and description in the figure). Further details on actual content are provided in section 2.2.

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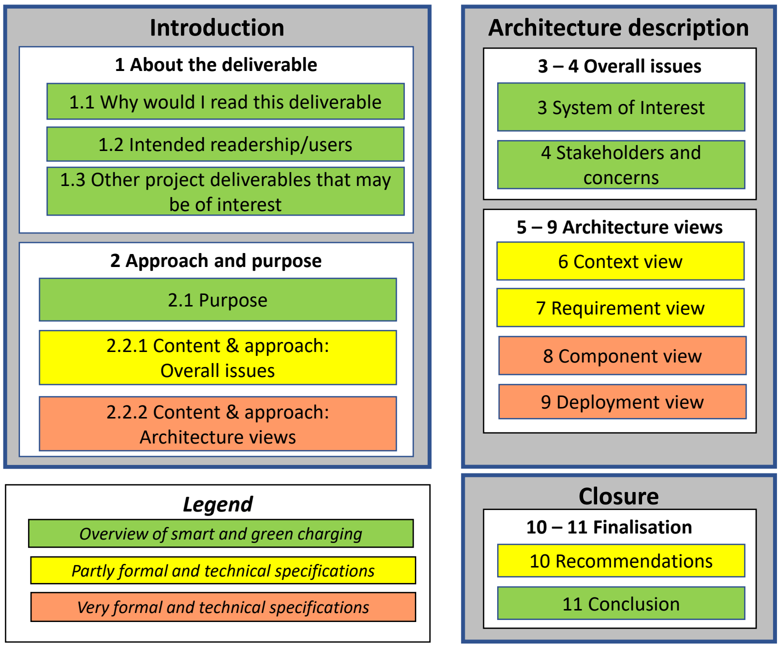

Green boxes provide overviews. In the introduction, they provide an overview of the deliverable and the purpose of it. In the architecture description, they provide an overview of the GreenCharge concept.

Yellow boxes are to some extent models and formal specifications. However, readers with special interest in eMobility, but without a technical background, might find the content useful.

Red boxes are very formal and technical specifications targeting readers doing technical design and development of software solutions.

Figure 1-1 Categorisation of the sections in the deliverable

In general, **stakeholders** with interest in smart and green charging should read the green parts of the deliverable to get an overview.

Users of charging services or buyers of charging services/products (e.g., property owners, housing cooperatives, employers, fleet operators, etc.) may in addition read the yellow context and the yellow requirement views to get input on which functionality they should request. In this way, they will also increase their understanding of the green and smart charging opportunities and thereby get in a better position when services/products are chosen/purchased.

Policy makers can through the green sections get a better understanding of the GreenCharge concept and thereby get in a better position to influence the transition towards sustainable e-mobility.

Commercial actors within eMobility (e.g., emobility service providers, system owners, charge service providers, entrepreneurs and other businesses) will though the green parts get a better understanding of the role they can play. They may also use the yellow context and requirement views to get input on the requirements to their system components.

System designers and software developers should read the yellow context and requirement views and red component view to get input to the design of technical solutions. In addition, they should use the guidelines and examples provided in the red deployment view to do the design of the physical system components.

1.3 Other project deliverables that may be of interest

Many deliverables provide the basis for the different architecture aspects addressed by this deliverable and may be of interest to the reader:

- **D5.4 /D6.3** Intermediate Result for Innovation Effects Evaluation / Intermediate Evaluation Result for Stakeholder Acceptance Analysis (Natvig, Enrich et al. 2021). The lessons learned and evaluation results are used to refine the motivation models (see Annex C) that are the basis for the *concerns* in section 4.2 and the requirements *view* in chapter 6.
- **D2.3/D2.9/D2.16** Description of Oslo/Bremen/Barcelona Pilot and User Needs (Søråsen, Mork et al. 2019) (Günther, Dittrich et al. 2019) (Enrich, Rodríguez et al. 2019). These deliverables provide pilot use cases. These use cases have been defined as reference use cases in this deliverable. The *use case model* in section 5.1 builds upon the description of the Green Charge pilots:

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- **D5.6** Open Research Data (to be published at the end of the project). The information models in section 7.1 are aligned with the research data.

The reference architecture presented in this document has provided inputs to the following deliverables:

- **D4.5** Final version of Integrated Prototypes (to be published by the end of the project). This document specifies the prototypes deployed at the pilot sites (different instances of the integrated pilot). The specification will use the reference architecture as a blueprint both for the local GreenCharge solutions and the automated data collection needed for evaluations and simulations.
- **D5.3** Simulation and visualisation tool (Esposito, Aversa et al. 2021): This deliverable depends on automated data collection from the pilot sites, and the data collection will be accomplished as described in D4.1.
- **D5.5** Final Result for Innovation Effects Evaluation (to be published by the end of the project): This deliverable depends on automated data collection from the pilot sites, and the data collection will be accomplished as described in D4.2.

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2 Approach and purpose

2.1 Purpose of the reference architecture description

The overall goal of the GreenCharge project is to encourage the electrification of the transport sector by:

- Enabling more available, efficient, and user-friendly charge services.
- Enabling more sustainable electric energy supply for the charging.
- Minimizing the need for costly extensions of the electricity grid due to charging.
- Enabling the necessary growth of the charging infrastructure.

This will be achieved through a realisation of the GreenCharge concept.

The electric energy supply sector is a mature and highly regulated sector with a well-established structure and supporting technical systems. Also, for e-mobility sector, a business structure with business actor roles and supporting appliances and business systems has already emerged. Our approach to realizing the GreenCharge concept is to extend the functionality of and the collaboration between these already existing systems.

A main purpose of the GreenCharge reference architecture presented in this document is to specify the participation of relevant existing systems in the realization of the GreenCharge solution in terms of *modified and/or or added responsibilities and collaboration patterns necessary to support the GreenCharge concept*.

Figure 2 describes the role of a reference architecture description. It supports the realisation of the new and/or added aspects that together facilitate the implementation of the system of systems that realise the GreenCharge concept.

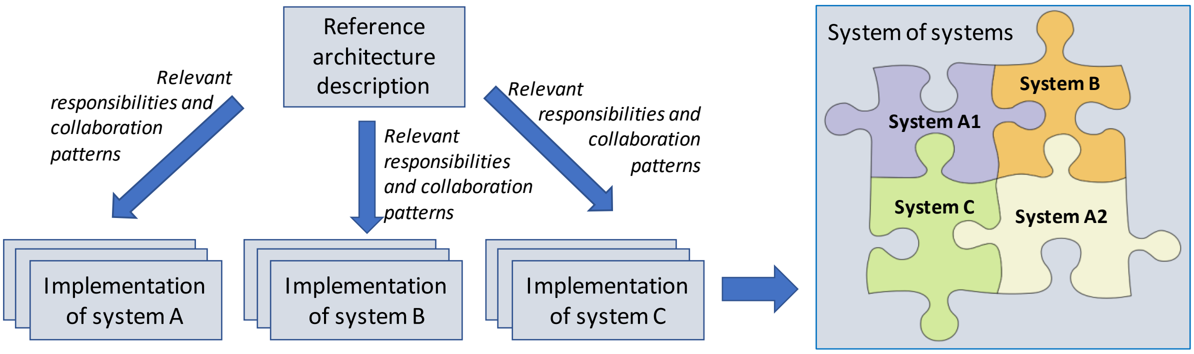

Figure 2-1 The role of a reference architecture description

The reference architecture description shall support the understanding of the GreenCharge concept and serve as a blueprint for planning and construction of systems and/or system components (new as well as modifications and extensions of existing systems) that together realise the concept. Thus, the architecture content cannot enforce a particular structure on the set of participating systems but describes a possible architecture for systems that collaborate to implement the concept.

As in each pilot and in other deployment sites, there are local business actors involved with their own existing systems that need to be adapted and extended. Therefore, the GreenCharge architecture description needs to be open to different concrete underpinning technologies, and each pilot need to specialize the relevant parts of the reference architecture description for their situation by specifying the exact technologies to be included and how they need to be modified and extended to comply with the architecture.

The architecture description addresses a full-fledged implementation for the whole GreenCharge concept. This is a generalisation of what is demonstrated by all the pilots and in the scenarios demonstrated using simulation techniques. Each GreenCharge pilot will demonstrate a selected sub-set of GreenCharge concept according to the local contexts and needs. The full-fledged scope of the architecture description is necessary for the ability to serve as basis for future exploitation and deployment of the GreenCharge ideas.

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2.2 Reference architecture description content and approach

The architectural work is guided by the ARCADE framework and the standard *ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description (ISO/IEC/IEEE 2011)*. Details on these frameworks and the architectural terminology and concepts are in Annex A.

Figure 3 shows the architecture description part of the reference architecture from Figure 1 are provides an overview of the input provided and the relations between the different parts of the architecture description.

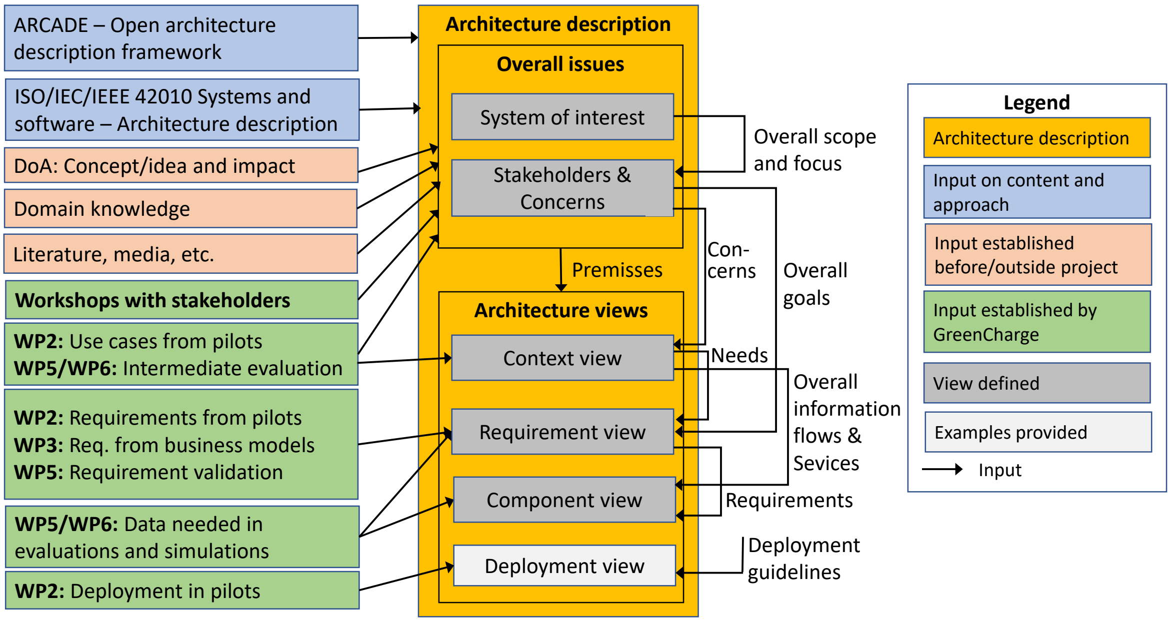

Figure 2-2 GreenCharge reference architecture description content and approach

To fulfil its purpose, the architecture description contains specifications that support the realisation of the GreenCharge concept. In addition, it contains short descriptions of how the different parts of the architecture description can be used to serve as a blueprint for more concrete system architectures.

As indicated by the left side of Figure 3, the reference architecture description is based on input from many sources:

- The ARCADE framework and ISO/IEC/IEEE 42010 provided input on the content to include and the overall approach.
- The project description (GreenCharge Description of Action - DoA), domain knowledge (knowledge on existing solutions included) in the project consortium (established before the start of the project), and literature and information generated outside the project were used as a starting point for the overall issues.
- GreenCharge results from different WPs and workshop results provided input to the refinement of the overall issues and to the content of different architecture views. This also includes input from intermediate evaluation and the validation of the initial set of requirements (as described in D5.5).

As indicated by the arrows between the different parts of the reference architecture in Figure 3, there are dependencies between the parts. One part may provide a starting point for other parts.

2.2.1 Content and approach: Overall issues

As depicted in Figure 3, the overall issues part of the architecture description describes the system of interest, the stakeholders holding concerns for the system of interest, and the concerns of these stakeholders.

System of interest: The system of interest is a system realising the GreenCharge concept. The overall needs to be supported are to a large extent defined by Annex 1 of the GreenCharge Description of Action (DoA). The functionality needed is summarised. In addition, the following model is used to define the domain:

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- *Domain concept model* expressed by UML 2.0 class diagrams. The model defines important concepts and terms used in the reference architecture description and the relations between the concepts and terms.

Stakeholders & Concerns: The stakeholder types of relevance are identified through analyses of the different focus areas addressed by the system of interest and through existing specifications of the eMobility sector such as the IEC 63119-1 (IEC 2019) and reports (Netherlands Enterprise Agency 2019). The project consortium also holds considerable domain knowledge that is used to identify the relevant stakeholder types.

Initially, the concerns were identified though European policy documents (European Commission 2011), the work of the EMI3 group (https://emi3group.com/), input received through networks and related seminars (e.g. emobility associations) and stakeholder involvement at GreenCharge workshops. The project has arranged workshops with external actors to get input on business model related concerns, and one dedicated workshop where the project partners representing different stakeholder types provided input on motivations, barriers and current status from their point of view. Finally, the concerns were refined based on the intermediate evaluation results from WP5. The following model kind is used to explore and document the concerns of the stakeholder types and to identify goals to achieve to overcome barriers:

- *Motivation model* expressed by ArchiMate motivation model elements (http://pubs.opengroup.org/architecture/archimate3-doc/toc.html) (Aldea, Iacob et al. 2015).

2.2.2 Content and approach: Architecture views

As depicted in Figure 3, the architecture views part of the architecture description describes the architecture views. These views are described according to relevant viewpoints that are selected to support:

- The need for a common understanding of the GreenCharge solution. The extensions needed for smart and green charging are emphasized. Some issues in addition to this are however also included to show how the extended solution relates to traditional functionality.
- System integrations. The GreenCharge solution is based on integrations of existing systems, which are extended to support smart and green charging.
- The reference architecture approach. Detailed requirements to functionality that will be specific to the individual systems and the realisation of physical system components are not addressed since these aspects will vary from system to system.

These viewpoints guide the establishments of the related views, the use of model kinds included. All models were modelled in the Architecture Enterprise tool (see https://sparxsystems.com/products/ea/). The model kinds used are

- UML 2.0 models (http://www.uml.org). The model types are further described below.
- Motivation models modelled by means of ArchiMate motivation elements (http://pubs.opengroup.org/architecture/archimate3-doc/toc.html).describe the viewpoints

In the following we describe the selected viewpoints:

Context viewpoint: It aims for a common understanding of and a clear definition of the GreenCharge solution with respect to how it should work at a functional level. The model kinds used are:

- *Use case model* expressed by UML 2.0 use case diagrams. The model defines the required functionality, and the content is based on the identified concerns as well as input from the GreenCharge pilots.
- *Use case to service mapping model* defined by a combination of UML 2.0 use cases and components. The components are logical components stereotyped as "services" and not physical software components since the reference architecture description does not address the physical components implementing the solution. The model defines which use cases the different services support.
- *Environment model* expressed by UML 2.0 component diagrams. The model defines the external components which the GreenCharge solution may interact with.

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Requirement viewpoint: It aims to specify requirements regarding different aspects of the solution. However, since this is a reference architecture description, the requirements cannot be very detailed. They are overall and principal requirements that must be in place to realise the GreenCharge concept. Requirements addressing detailed functionality, user interface issues, etc. are not addressed. The model kind used is:

- *Motivation model* expressed by ArchiMate motivation elements. The model defines the overall requirements derived from the goals identified in the Stakeholder and Concerns part of the architecture description. These overall requirements are further detailed based on input from the context view, input from WP2 (on pilot related requirements), input from WP3 (on technical support for realisation of business models) and input from WP5/WP6 (on automated data collection needed for evaluations and simulations).

Component viewpoint: It aims to specify the logical components, i.e., the services identified in the context view, collaborate and interact. This includes the definition of the information exchanged and the definition of when and how the information is exchanged. The model kinds used to describe the component view are:

- *System information model* expressed by UML 2.0 class diagrams. The model defines the information classes of relevance and documents the information elements in each class.
- *System component and interface model* expressed by UML 2.0 component models. The model identifies and defines the interfaces used for communication between the services (logical components).
- *System collaboration model* expressed by UML 2.0 sequence diagrams. The model defines how the services will interact.

Deployment viewpoint: This viewpoint is not defined by the reference architecture description since the realisation in physical system components is not decided by the reference architecture. The deployment view should however be included in concrete system architectures based on the reference architecture description. Thus, this document has sections for the deployment view and provides

- *Advice* on how to establish this view in actual system architectures derived from the reference architecture description.
- *Content examples* from the deployment of systems in the GreenCharge demonstrrators.

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3 System of Interest

The System of Interest addressed by this reference architecture description is linked to the need for green and smart charging of electric vehicles (EVs), as described by the GreenCharge project. The System of Interest is also referred to as the GreenCharge solution and realises the GreenCharge concept.

3.1 Overall challenges

The main challenges to be solved are described below.

Potential electric vehicle owners worry about where they can charge their vehicle. Many people in Europe lack easy access to a charge point at or near their home – so they won't buy electric vehicles until they feel sure that publicly available charging infrastructure can be dramatically improved. Even if that is solved, a secondary issue arises: on arrival at the charging location, will they have to wait in a queue before being able to charge.

Potential charging providers hesitate to invest in provision of charging infrastructure. There is a "chicken and egg" problem here: people hesitate to buy electric vehicles because they worry about lack of charge points, potential charge point providers do not build charge points because they are unsure of receiving a good return on investment if not enough people buy electric vehicles.

Property owners may struggle to meet energy requirements. If people plug in their electric vehicles and expect to be able to charge right now, huge peaks of demand may arise on the electricity network. It would require major upgrades to be able to cope, the upgrades will take a lot of time, and the extension of the capacity will require major financial investments. This is a real "showstopper": unless some way can be found to avoid such peaks, widespread adoption of electric vehicles is not going to happen. The challenge applies both at the national level (i.e., the electricity grid as a whole) and at the local level (e.g., when an apartment block with parking places wants to offer all residents the ability to charge vehicles but does not have an electricity network with enough capacity).

The flexibility in electric vehicle charging is not utilised. The challenges linked to the high peaks described above can to some extend be mitigated by the nature of electric vehicle charging. The charging may in many be flexible – it can be postponed to a time when energy is available. This may be optimised at a local level (e.g., in a garage). The highest potential is however to consider all types of energy demands as well as local energy production and storage when the electric vehicle charging flexibility is utilised. This is so far not utilised to its full potential.

The energy used by the electric vehicles must be as green as possible. The motivation for the transition to e-mobility is to avoid the CO2 emission from fossil vehicles, which only happens if the electric vehicles are charged with green electric energy. Thus, to meet the international goals on reduction of emissions, the electrification of the transport sector must as far as possible be based on green and renewable energy.

3.2 Overall functionality

The functionality provided by the System of Interest supports the GreenCharge concept through facilitating **cross sectorial collaboration** involving business actors and supporting technical systems of both the energy supply, transport and building sectors. Electric vehicles, charge management and local energy management work together to facilitate a transport system running on green energy.

To support the above, it must be possible to

- Receive information on energy demands and flexibility in advance, energy demands for charging, charging flexibility, and other user of energy included.
- Optimise the energy use according to the needs and possibilities in an energy smart neighbourhood, where energy demands (flexibility included), energy import/export, local energy production from renewable energy sources, and local energy storage are predicted, managed, and coordinated.

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- Adapt the charging of electric vehicles to optimal energy use. This also includes support for V2G, where connected vehicles can be used as stationary batteries for local energy storage.
- Enable roaming services that facilitates such optimal charging across service providers.

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4 Stakeholders and concerns

4.1 Stakeholders

Note that the architecture description uses generic stakeholder archetypes with non-overlapping responsibilities and scopes to specify concepts and the solutions. Figure 5 shows the stakeholder archetypes addressed. In the following, they are usually referred to as stakeholders.

The stakeholders holding concerns for the system of interest, categorised as:

- *Primary stakeholders* that take the initiatives. These are EV User, EV Fleet Operator, and Energy Consumer/Prosumer.
- *Secondary stakeholders* that respond to the initiatives of the primary stakeholders. These are the eMobility Provider (EMP), Charge Point Operator (CPO), Local Energy Manager (LEM) and Roaming Operator.
- *External stakeholders* that are not involved in the GreenCharge solution but contribute to the solution. These are the Public Grid Actor and the Traveller.

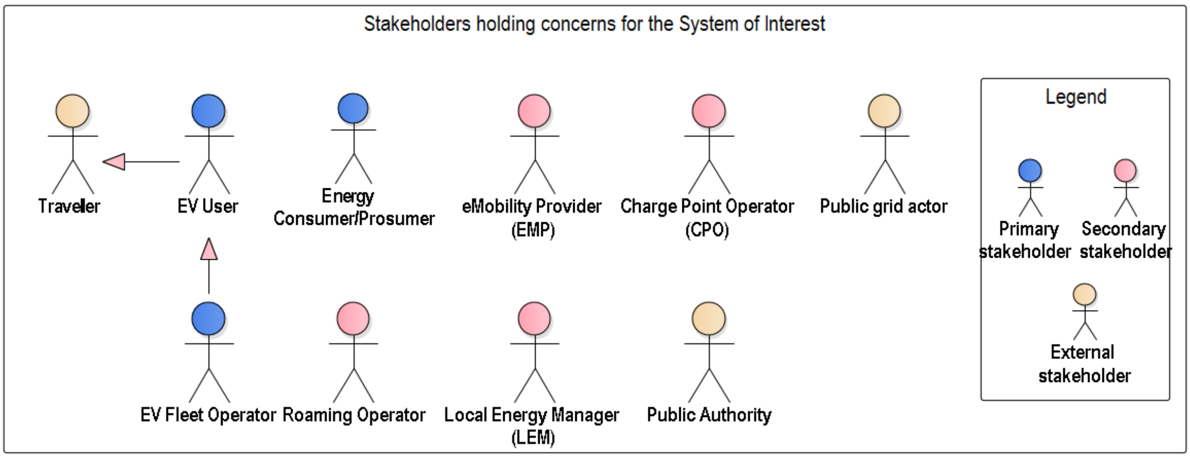

Figure 4-1 Stakeholders of relevance

The stakeholder definitions below are based on IEC 63119-1 (ISO/IEC/IEEE , IEC 2019, IEC 2019) as well as other documents describing the emobility domain (Netherlands Enterprise Agency 2019). The definitions are adapted to clarify the role of the stakeholder in relation to the GreenCharge concept.

EV User is a person or a legal entity using one or more electric vehicles (EVs). In GreenCharge, the EV User uses digital services to provide information about charging needs, or digital solutions may act on behalf of the EV User. The charging requests provided arranges for more optimal charging and may contain: A booking of a time slot at a charge point; a booking with energy demand flexibility (meaning that the electric vehicle may be charged at any time within a time limit); and V2G flexibility (meaning that the electric vehicle user allows that the battery of the electric vehicle is used as an energy source).

EV Fleet Operator operates a fleet of electric vehicles and assigns electric vehicles to customers or fleet operations (transport of persons/freight and other tasks) and monitors information about the electric vehicles. The EV Fleet Operator aims to adapt the charging of these electric vehicles to the planned use of the fleet. The EV Fleet Operator may also book charge points and request flexible charging. An EV Fleet Operator with a business agreement with an eMobility Provider (EMP) can be considered as an EV User, and the customers of the EV Fleet Operator will inherit the credentials of the EV Fleet Operators.

eMobility Provider (EMP*)* provides electric vehicle charge services to EV Users. EV Users may subscribe to services from the EMP. In such cases the EMP is the "home" EMP of the EV User. The EMP authenticates the EV User's credentials (physical or digital asset carrying the EV Users identity or contract ID) before charge services can be requested and provides the billing and other value-added services to the EV User. The EMP includes the CSP role defined in IEC 63119-1 and may provide roaming endpoints.

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Charge Point Operator (CPO) has business relations with one or more EMPs and is responsible for the provisioning and operation of the charging infrastructure (including charging sites) at charge stations and for managing electricity to provide requested energy transfer services. When an EMP or Roaming Operator has authorised the EV User, the CPO will receive and handle the charging requests (charge point bookings, energy bookings, V2G flexibility, etc.) from the EV Users. The CPO may also operate a roaming endpoint and provide functions that enable roaming. The CPO corresponds with the CSO role defined in IEC 63119-1 and may provide roaming endpoints.

Roaming Operator facilitates authorisation, billing and settling procedure for electric vehicle charge service roaming, between two roaming endpoints (operated by EMPs and/or CPOs). Roaming allows EMPs to provide charging services on charging equipment operated by multiple (ideally all) CPOs, thus alleviating the need for users to deal with multiple EMPs. The Roaming Operator corresponds with the Clearing house role defined in IEC 63119-1 and enables roaming. Different actors may take the Roaming Operator role. An actor that has the EMP role may for example also take the Roaming Operator role.

Local Energy Manager (LEM) manages the use and storage of energy in a local energy community or a part of such a community (building, neighbourhood, area, charging infrastructure, etc.) and plans and controls the energy use of the associated energy demanding activities, electric vehicle charging included, dependent on current and foreseen future energy demands and energy availability. The LEM manages how the energy from local RES (e.g., PV panels), stored energy (from stationary batteries and V2G) and energy from the grid are used. Note that there might be a hierarchy of local energy management systems that communicates, and there will be a LEM for each of system.

Energy Consumer/Prosumer executes energy demanding activities in its apartment or building and may also produce and store energy. Depending on the energy demand flexibility provided, the energy management system of the LEM will plan and schedule the energy use of energy demanding activities and use the locally produced and/or stored energy to arrange for more optimal use of energy. This may be a building inhabitant, a building owner, or a renter that have equipment and installations that requires energy. This may also be an energy demanding device.

Public Grid Actors are Distribution Service Operators (DSOs), Transmission System Operators (TSOs), and retailers. They operate the energy distribution system, define tariffs, and may request demand response from the energy management system of the LEM.

Traveller needs to go from one place to another. This need can be fulfilled in many ways, e-mobility included. Travellers may for example request electric vehicle sharing services from EV Fleet Operators. In such cases the traveller will become an EV User. The EV User is a specialisation of the traveller.

Public Authority will make the policy for the transition towards e-mobility and address how the transition is to be accomplished in a Sustainable Urban Mobility Plan (SUMP). Policy constraints will be input to the GreenCharge solution.

Note that the use of stakeholder archetypes supports generic specifications that can be applied in several ways. In the real world, one actor may play the role of one or more stakeholder archetypes:

- A CPO actor may also provide charge services to EV Users. In such cases the CPO actor plays the role of both the CPO and the EMP stakeholder types.
- A CPO actor may also do optimisation of the energy use for charging of electric vehicles connected to charge points depending on the energy availability. In such cases the CPO actor also plays the role of a LEM (a LEM for the part of the grid that includes the charge points).
- An EMP actor may operate a roaming endpoint, meaning that the EMP provides functions that arrange for roaming. In such cases, the EMP actor will also be a Roaming Operator.
- An EV Fleet Operator actor may also provide charge services and thus also play the role of an EMP.
- An EV Fleet Operator may also request charging from an EMP and thus also play the role as an EV User.
- An EV User may also be an Energy Consumer/Procumer.

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Actors not directly addressed by the GreenCharge project may also take some of the roles represented by the stakeholders listed above, for example:

- Parking operators may be an EMP when they enable access to charging stations installed on their parking lot through their parking app.
- Taxi and bus companies operating electric taxies and buses are EV Fleet Operators. Electric buses will however need special charge stations. These charge stations may compete about the available power or energy, probably with high priority.

4.2 Concerns

As described in the DoA, the GreenCharge project aims to facilitate the GreenCharge concept, aiming for smart and green charging of electric vehicles. Thus, the overall concerns of the stakeholders identified in 4.1 with respect to this.

The stakeholder concerns are analysed through a structured approach using ArchiMate motivation models as described in Annex C. For each stakeholder, the motivations for a change towards eMobility and green charging are identified and analysed. This includes the identification of the drivers for such a change, assessments of the current status with respect to the drivers, and goals that must be reached to support the drivers.

A complete list of the goals derived from the work on motivation models is provided in Table 2. These goals are the starting point for the overall requirements defined in Chapter 6. The goals are categorised as follows:

- Goals related to Smart Charging (SC)
- Goals related to Energy Management (EM)
- Goals related to Roaming Management (RM)
- Goals related to electric vehicle Fleet Management (FM)
- Goals related to Public Policy (PP)

Use of the goals as a blueprint in system architecture descriptions: The goals of relevance will depend on the stakeholders and concerns of relevance identified by means of the motivation model. The goals of relevance should be prioritised to guide the implementation process.

Table 4-1 Goals to meet stakeholder concerns, derived from motivation models

ID	Goal	Description	Category
G1	**Sufficiently many and conveniently located CPs**	The charging infrastructure in the city must be adapted to needs. It must be easy for EV Users to find available charge points (CPs) in the vicinity when charging is needed.	PP
G2	**Seamless access to CPs across operators**	Charge points should in general be open to all EV Users, independent of which operators the EV Users have a business agreement with. Settlements between operators should arrange for seamless use.	RM
G3	**Predictable CP availability and low waiting time**	The charging of electric vehicles must be predictable. Information about charge point availability and/or the expected waiting must be available. The waiting time should be as low as possible. The EV User must be supported to find a charge point and a time where and when the waiting time is acceptable.	SC

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ID	Goal	Description	Category
G4	**Digital assistance for smart charging**	An App should support the communication between the EV User and the system. The required planning and preparations should not require as little interaction with the system as possible. Default values should cover repetitive use patterns, and smart and informed decisions should be supported. Feedback from the system should ease the understanding of the smart charging concept and motivate the EV User to take smart decisions.	SC
G5	**Attractive user interface for smart charging**	Smart charging must be supported by a user interface that reduces as much as possible the effort needed to provide preferences and constraints for the charging and payment. The user must be allowed to configure the solution to support • Preferred options, e.g., the preferred payment option. • Default values that can minimize the need for provision of input parameters (e.g., the most likely charging patterns for the user). Decision support must be provided when decisions are to be taken. The user must be motivated through the provision of status information and statistics showing the effects of smart charging.	SC
G6	**Facilitate that flexibility is rewarded**	Energy demand flexibility in electric vehicle charging arrange for an adaption of the charging to the energy availability (and if relevant, also to the availability of green energy). Such flexibility must be rewarded since it contributes to a reduction of peak loads. Business models must take this into account and reward such energy demand flexibility. The charging costs must be lower compared with charging costs when no flexibility is provided.	SC EM
G7	**Smart energy management**	The energy production, storage and use are managed in a way that arrange for good decisions on • The storage of energy in local energy storage (V2G included) • The scheduling and execution of energy demanding activities by means of energy from different energy sources (grid, energy storage, RES, V2G, etc.). Energy demands and constrains (e.g., latest finalisation time and priorities) are considered.	EM
G8	**CP used according to plan and not blocked**	The use of charge points is followed up, and deviations from usage plan are managed. Deviations that might be detected are • Unauthorised use of charge points. Charging will not be allowed unless the user is registered. • Blocking of charge point by fully charged electric vehicle when use of charge point is just allowed during charging • Blocking of charge point when booked time slot is expired	SC
G9	**Digital assistance for identification of available CP timeslots**	EV Users must get digital support for • The identification of available charge point timeslots • Booking of available timeslots for charging. Such support can distribute the use of charge points in a better way and provide more predictable access to charge points.	SC

ID	Goal	Description	Category
G10	**Flexible charging adapted to energy availability**	EV Users might allow flexible charging, i.e., that the charging can be done at any time if it is completed before a deadline. In such cases, the charging can be distributed over time and adapted to the availability of energy and transfer capacity according to pre-defined rules (e.g., that the use of green energy should be prioritised)	EM
G11	**Production of green energy is encouraged**	Solutions and business models must arrange for advantages to inhabitants who invest in renewable energy production from local RES. It must be possible to get return of investments through • Self-consumption of green energy • Production of green energy • Storage of green energy until the use of it is advantageous • Sales of green energy Collaboration among inhabitants to maximize the return of investments	EM
G12	**Increase awareness of members of energy smart neighbourhoods**	Energy Consumer/Prosumers, EV Users and others with energy demanding activities must be motivated to take part in smart energy management. They must get information on the ability to affect costs and CO2 footprint. The smart energy management must be supported by viable business models.	EM
G13	**Attractive user interface for energy management**	Energy Consumer/Prosumers, EV Users and others with energy demanding activities must be supported when smart energy management is to be planned and executed: • It must be easy to use of Apps and systems for smart energy management. The user must be supported when the solution is configured and used • The users must get support for informed decisions • The users must be inspired through feedback information on savings, reduction of CO2 footprint, etc.	EM
G14	**Charge planning integrated with fleet management**	The fleet management must take charging into account. Fleet management systems must adopt to smart charging and arrange for energy demand flexibility and use of green energy.	FM
G15	**Use green charging as a strategic measure**	The CO2 footprint reduction achieved through smart charging and charging with green energy must be registered and used in the marketing of the electric vehicle fleet.	FM
G16	**Roaming for new EMP types**	New charge services (e.g., sharing of private charge points and shared use of dedicated charge points) will also need roaming to facilitate that EV Users can use different charging. Thus, roaming services must support new types of eMobility Provider (EMP)s either directly or via the Charge Point Operator they are using.	RM
G17	**Roaming solutions for booking of charging**	It must be possible to book charge points across different eMobility Provider (EMP)s. Thus, roaming services must support the roaming of booking.	RM
G18	**Get EV fleet customers through MaaS**	The Fleet Operator can reach new customer groups through an integration of the transport services provided by the EV Fleet Operator into MaaS. When relevant, travellers using MaaS can get use of the electric vehicle /EV) fleet as an option. The MaaS operator will provide the user interface and indirectly do the marketing of the electric vehicle fleet through the marketing of MaaS.	FM

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ID	Goal	Description	Category
G19	**Economic incentives for use of EVs**	Different incentives can be used. For example: Electric vehicles (EVs) might have lower taxes than fossil cars, reduced toll road feed, reduces parking fees, etc.	PP
G20	**EVs have less restrictions in traffic**	Many European cities will probably introduce traffic regulation measures that put restrictions on the use of private cars. Electric vehicles should be less effected by such restrictions than fossils cars, and electric vehicles should also get advantages compared to fossil cars. Electric vehicles (EVs) may for example be allowed to enter green areas of the city.	PP
G21	**Increased share of EVs**	The share of electric vehicles (EVs) must be increased. The total number of private cars should however be reduced.	PP
G22	**Increased use of shared EVs**	To reduce the total number of private cars, the use of shared electric vehicles must be increased.	PP
G23	**Run living lab trials**	Smart charging, as an integrated part of energy smart neighbourhoods, must be demonstrated and evaluated to gain new knowledge and experiences.	PP
G24	**Simulate scenarios that cannot be tested in living labs**	Smart charging scenarios that cannot be demonstrated (e.g., scale ups and V2G) must be simulated and evaluated to gain new knowledge.	PP
G25	**Influence emobility awareness raising**	The decision makers and the public in general must be aware of the positive effects of emobility, and the acceptance of electric vehicles must be increase.	PP
G26	**Shared cars are preferably EVs**	The car sharing services offered in cities should offer electric vehicles.	PP
G27	**E-mobility policy**	The policies for city development and transport must address the transition towards emobility, and the policy must be implemented	PP
G28	**Facilitate that investments in RES and storage are rewarded**	Investments in local RES and storage arrange for optimal use of locally produced energy (also green energy) and must be rewarded since it contributes to a reduction of peak loads. Business models must take this into account and reward the prosumers.	EM
G29	**Other EV Users pay for use of available CP capacity**	The return of investment for private charge point is covered when the charge point is shared with others that may for the use of the charge point. The charge point can be shared when it is not needed by the charge point owner.	SC
G30	**Economically sustainable EV sharing**	The EV fleet operator must operate a viable business. The revenue must be sufficient, and the costs must not be too high. The policy of the public authorities should contribute to make this feasible in the stage when e-mobility is unmature and not in a position to compete with traditional transport services.	PP
G31	**Eco-driving**	The EVs should preferably operate in an eco-driving mode to avoid unnecessary wear and to protect the environment. Eco-diving will reduce the operating costs.	FM

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5 Context view

The context view includes:

- Use case model. It defines functionality and more detailed concerns regarding the solution.
- Use case to service mapping model. It defines the logical services needed and which use cases that are covered by the different services.
- Environment model. It defines the external components which the solution may interact with.

5.1 Use case model

The overall functionality provided by the System of Interest is illustrated by the reference use cases in Figure 6. The notation used is described in B.2. The stakeholders are defined in section 4.1, and the functionality associated to the use cases are described below.

Note that the use cases are reference use cases. They are open to different levels of implementation to support the evolution of smart and green charging.

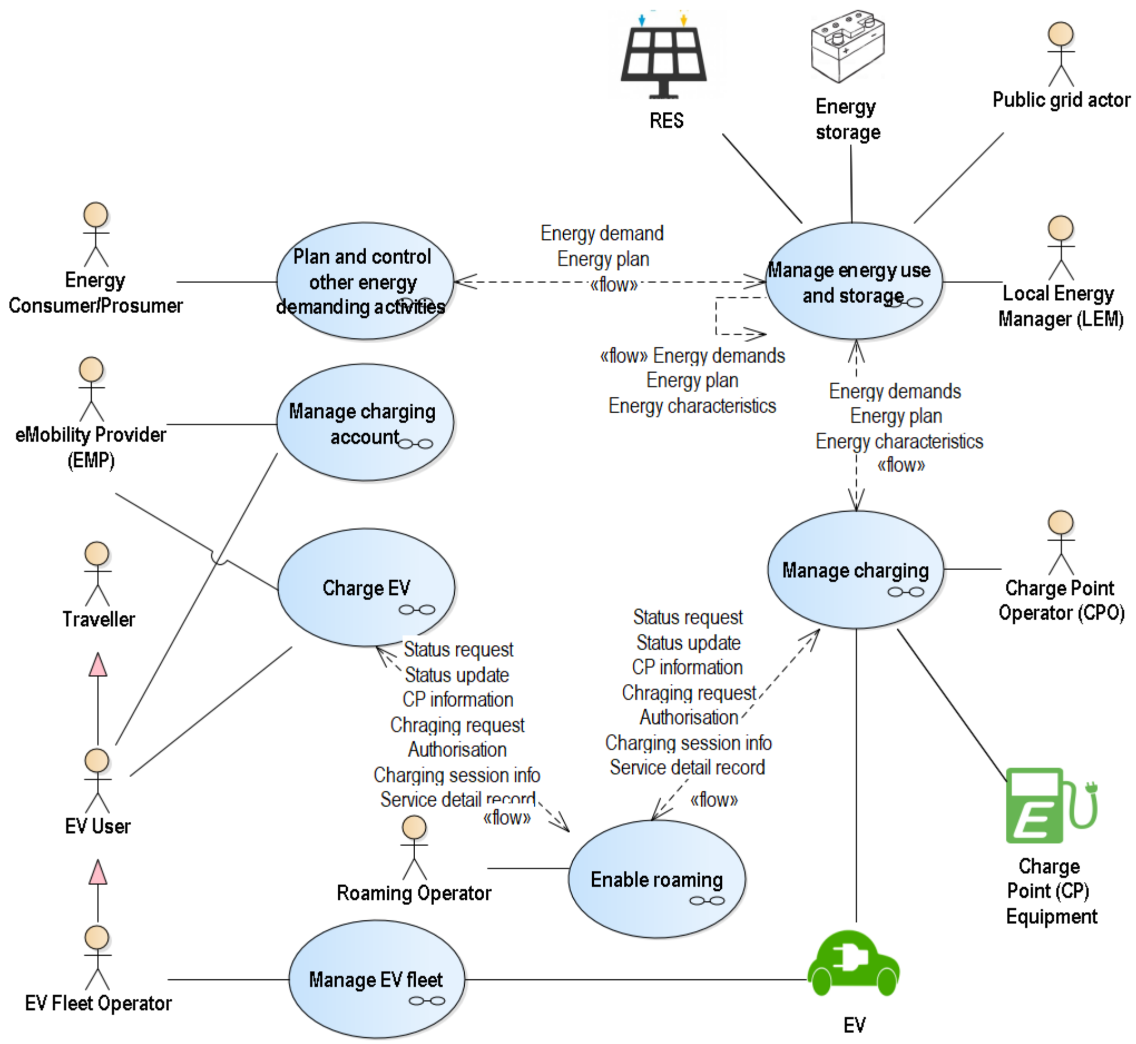

Figure 5-1 Overall functionality provided by the System of interest

To arrange for flexibility, the information exchange between the EMP and the CPO is directed via the Roaming operator. The role of the Roaming operator stakeholder may be covered by different actors, e.g., third party roaming providers or the EMP itself.

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Use of this model as a blueprint in system architecture descriptions: Use cases of relevance should be identified. The use cases can be refined and adapted to reflect the functionality needed in the actual system. The information flows of relevance should be identified.

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5.1.1 Manage charging account

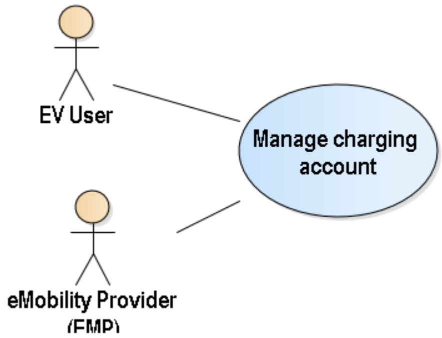

Figure 5-2 Manage charging account use case

The use case is for the Emobility Provider (EMP) and EV users to manage the EV User's profile and subscription.

Pre-condition/trigger event: An EV User takes the initiative to subscribe to services from an EMP, to update or cancel a subscription, or to register or update the EV User profile.

Post-condition: EV User leaves the charging account.

Description:

1. A subscription is managed:
    - The EV user establishes and manages a subscription offered by an EMP.
    - If the EV user is a Service provider (e.g., a Fleet Operator or a MaaS provider), the customers of these service providers may inherit the credentials of the service provider.
2. The EV User establishes and manages a user profile. The user profile contains information about
    - The EV User, e.g., contact information, notification channel, payment/invoice information, etc.
    - The electric vehicles (one or more) used by the EV User, e.g., registration numbers, type of electric vehicle, battery capacity, etc.
    - Preferred default values for the EV User in general and per electric vehicle are established. This may for example be whether V2G are allowed (yes or no), flags indicating the feedback wanted on the charging process (e.g., status update when charging is finished), priority setting, minimum charging level, the time for charging, etc.

5.1.2 Charge EV

Today, EV Users manually plan when and where to charge. In the future, the charge planning and follow up may become an integrated part of the travel planning and navigation support. ICT systems may act on behalf of the EV User and for example plan the charging and do the charge booking whenever this is required. In GreenCharge, we do however not distinguish between what is done by the EV User and a system representing the EV User. We refer to both as the EV User.

When the charging is flexible, it may take place at any time before a time defined by the EV User. The EV User can at any time get updates on the charging status.

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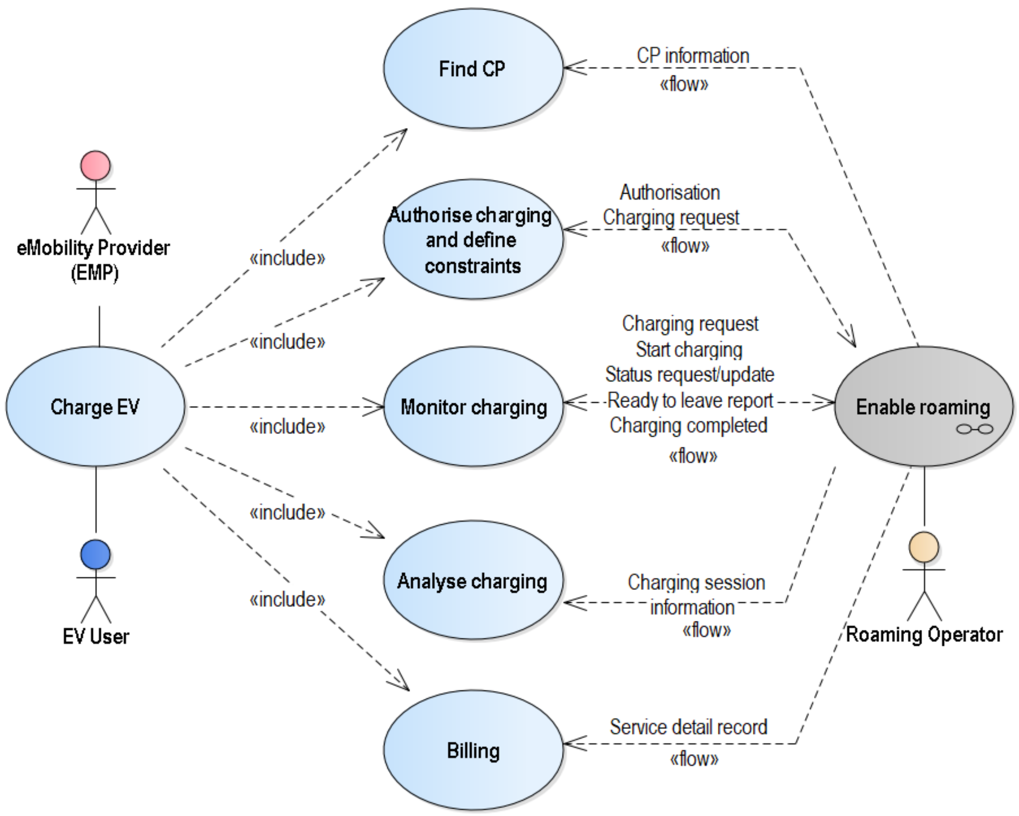

Figure 5-3 Charge EV use case

The use case includes the following use cases:

Find CP

Pre-condition/trigger event: When charging is needed or when the current charging plan needs an update

Post-condition: A charging location and a timeslot (in case of booking) that suits the EV User are identified.

Description:
1. Charge point information (locations, characteristics of the charge points, the availability of charge points, prices, etc.) on relevant charge points is received via the Roaming Operator.
2. A charge point that fits the journey plan of the EV User, the EV (connector types), and the required charging speed is identified.
3. The charge plan is established or updated.

Authorise charging and define constraints

Pre-condition/trigger event: Before charging. 1) When a suitable charging location is identified, and the EV Users wants to charge at this charge point; or 2) When a charging request must be changed or deleted.

Post-condition: The charging request is approved or rejected.

Description:
1. An *authorisation request* is sent to the EMP via authentication methods (via App on a mobile phone or another device, e.g., in the EV).
2. The EMP verifies the user subscription or customer information and sends an *authorisation response (authorisation confirmation* or *rejection)* to the CPO for the selected CP via a Roaming Operator (see use case "Enable roaming").
3. The CPO sends the EMP an *acknowledgement* of the received EMP authorisation via the Roaming Operator.

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4. The EV user defines a charging request. The EV user may get support from an App or another system (e.g., the navigation system). Default values and automation should be used to reduce the workload. The request may include a booking of a charge point, an energy demand with constraints, and a V2G flexibility offering. The request will define:
    - Priority (optional). High priority bookings may cause cancellations of other bookings.
    - Time period in which the charging should take place (earliest start time and latest finish time)
    - Minimum charging level (to be charged as soon as possible)
    - Initial State of Charge (SoC) when the electric vehicle is connected
    - The SoC to be reached
    - Minimum charging level when V2G
    - Status requests
    - Flag indicating that V2G is allowed
5. The charging request with authorisation is sent to EMP.
6. If the EMP approves the charging request, a charge session id is returned to the EV User. The charging request with the authorisation confirmation is sent to the Roaming Operator, which will forward this to the corresponding CPO.

Exception (with reference to the steps listed above):

2. If the authorisation fails, the interaction is terminated, and the charging service will not start.

6. The EMP reject the charging request, the interaction is terminated.

Monitor charging

Pre-condition/trigger event: Just before, during and just after the charging. Triggered by the actual charging or related events.

Post-condition: The charge point and the timeslot (in case of booking) that suits the EV User are identified. The EV User can monitor the charging status (e.g., progress and speed) and handle deviations.

Description: Handles the information exchange between the Roaming Operator and the EV User related to upcoming and ongoing charging sessions. Interactions are required in several situations:

1. Status update:
    - The EV User is notified according to the user preferences. The EV User may for example get a status update with a notification some time before the start of a booked charging and when the charging is completed.
2. CP selection support: On arrival to the charging location, the EV User is supported in the selection of the CP to use.
    - The user interface on the charging equipment (displays and signalling) will indicate whether a CP is booked, available, out of order, etc. If no booking is done, the EV User must select a CP that is available and send a *charging request*. When the EV User is authorised (see the "Authorise charging" use case), the charging can start.
    - When a charging point is pre-booked (in such cases the EV User is already authorised), the Roaming Operator will provide information to the EV User via a digital service on which charge point to use.
3. Charging start:
    - At the start of the charging, a *start charging* message is sent via the Roaming Operator.
    - Provided that the EV User is authorised to use the charge point, the EV can start the charging.
4. During charging:
    - The EV User may send status requests and receive status updates.
    - The EV User must decide how to cope with the deviations. If the EV User wants to report a fault, this use case supports the reporting.
5. Charging end:
    - When ready to leave (plug-out), a *ready to leave* message is sent to the Roaming Operator.

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.

Analyse charging

Pre-condition/trigger event: After charging, and when charging session information is received from the Roaming Operator.

Post-condition: The charge point and the timeslot (in case of booking) that suits the EV User are identified.

Description: The EMP records the detailed service records from a Roaming Operator and provides analysis and statistics on charging sessions. The EV User will get an overview of the analysis and statistics, e.g., the savings (with respect to both costs and emissions) gained due to smart and green charging, V2G energy delivered, the average grid mix during charging, etc.

Billing

Pre-condition/trigger event: After charging, and when billing and payment is needed.

Post-condition: Billing and payment is done for the charging session performed.

Description: The EMP will do billing and request payment based on a service detail record received from the CPO.

5.1.3 Manage EV fleet

The EV Fleet Operator may for example operate:

- A fleet of shared EVs for private or business users. In such cases the EV User will be a a specialisation of Traveller.
- A fleet of utility EVs. In such cases the EV User will in most cases be an employee of the EV Fleet Operator.

Note that the EV Fleet Operator is a specialisation of an EV User, and that the users of the fleet will also be EV Users. Thus, the charging of the EVs in the fleet is covered by the use cases of the EV user.

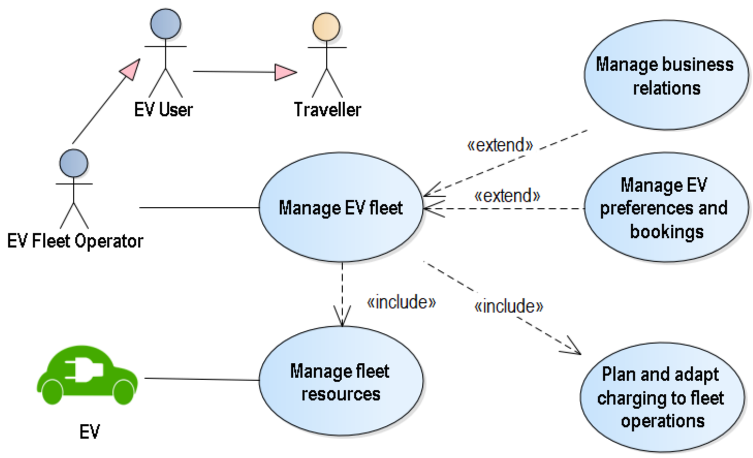

Figure 5-4 Manage EV Fleet use case

The "Manage EV fleet" use case has a focus on the charge planning as a part of the fleet management and the adaption of charging to the upcoming fleet operations. Depending on the situation, the use case includes and may be extended by the following use cases:

Manage business relations

Pre-condition/trigger event: The fleet is used in a commercial EV sharing service. This use case is triggered when an EV Fleet Operator establishes, updates or cancels business agreements with customers.

Post-condition: A business agreement is in place, updated, or cancelled.

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Description: The business relations may be directly with a Traveller or indirectly with a Traveller via a third party like for example a service provider. In any case, the use case will cover one or more of the following issues, depending on the type of electric vehicle offered:

1. Manage information about the EV user (i.e., the traveller).
2. Verify the driver licence of the EV User.
3. Offer information to the EV User on prices and business rules. Incentives may motivate for desired behaviour. The price may vary depending on the use of the electric vehicle (e.g., eco mode may be rewarded) and the check-in locations. Fines may be added, and advantages may be registered on the user (e.g., extra time) according to the incentive rules (e.g., incentives such as advantages that can be gained and fines for undesired behaviour or misuse).
4. Mange agreement on the use of the vehicle (vehicle type, period of hire, terms, pick-up location, etc.).
5. Manage dialogues with user on questions regarding the use of the electric vehicle.
6. Provide access to the vehicle (key or keyless access)
7. Manage billing and payment.

Manage EV preferences and bookings

Pre-condition/trigger event: The fleet is used in a commercial EV sharing service. A Traveller or service provider takes the initiative to book an electric vehicle.

Post-condition: The EV preferences and bookings are established and updated.

Description: The use case supports

1. The specification of the electric vehicle preferences
2. The definition of the expected use of the electric vehicle (duration, check-in location, etc.).
3. The booking of an electric vehicle. The Traveller may be offered electric vehicles that are charged through smart and green charging. (The booking will not be approved if previous fines are not paid)
4. The selection of charging alternatives in case the Traveller must charge the electric vehicle during use. The Traveller may be offered to use
    - The subscription of the EV Fleet Operator – to ensure smart and green charging and to get the charging costs on the bill from the EV Fleet Operator.
    - His/her private subscription.

Plan and adapt charging to fleet operations

Pre-condition/trigger event: The EV Fleet Operator needs to plan the charging of electric vehicles according to the needs of fleet operations.

Post-condition: The fleet of electric vehicles is charged according to the needs of fleet operations.

Description: This use case assists the EV Fleet Operator to ensure that fully charged electric vehicles are available to the customers and that the electric vehicles are charged to the extend needed before pick-up. The EV Fleet Operator is a specialisation of the EV User, and due to this, this use case is a specialisation of the "Charge EV" use case, and charging requests are adapted to the fleet operations before sent to the Roaming Operator (see *Figure 6)*. The charging request may include bookings of charge points and energy as well as V2G and energy demand flexibility offerings. When doing so, the EV Fleet Operator will take the role of an EV User.

Manage fleet resources

Pre-condition/trigger event: On EV (check-out) and (check-in), and during use

Post-condition: EV is checked in and fully charges.

Description:

1. Check-out and check-in are managed. This EV User will authenticate before electric vehicle check-out get keyless access) and conditions will be checked (e-g- driving licence). The EV User will also electronically check-in the electric vehicle electronically.

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2. At any time, the EV can be monitored through reception of status updates. Information such as milage, State of Charge (SoC), use of the eco-diving mode, etc. can be received. Information on charging deviations received from the EV user.
3. For shared EVs, the check in location may vary. Depending on the location (at charge station and tracking or not), the user may get a reward or a fine.
4. The EV User may be allowed to use the subscription of the EV Fleet Operator when charging.

5.1.4 Manage charging

The use case is the CPO's management of the smart charging and the operation of the charging infrastructure. Note that all information exchange with the EMP as well as the sharing of CP information are done via the Roaming Operator. The charge management is integrated with the Local Energy Manager to facilitate an adaption to the energy availability through flexible charging. The degree of flexibility provided (Junker, Azar et al. 2018) may also guide the pricing.

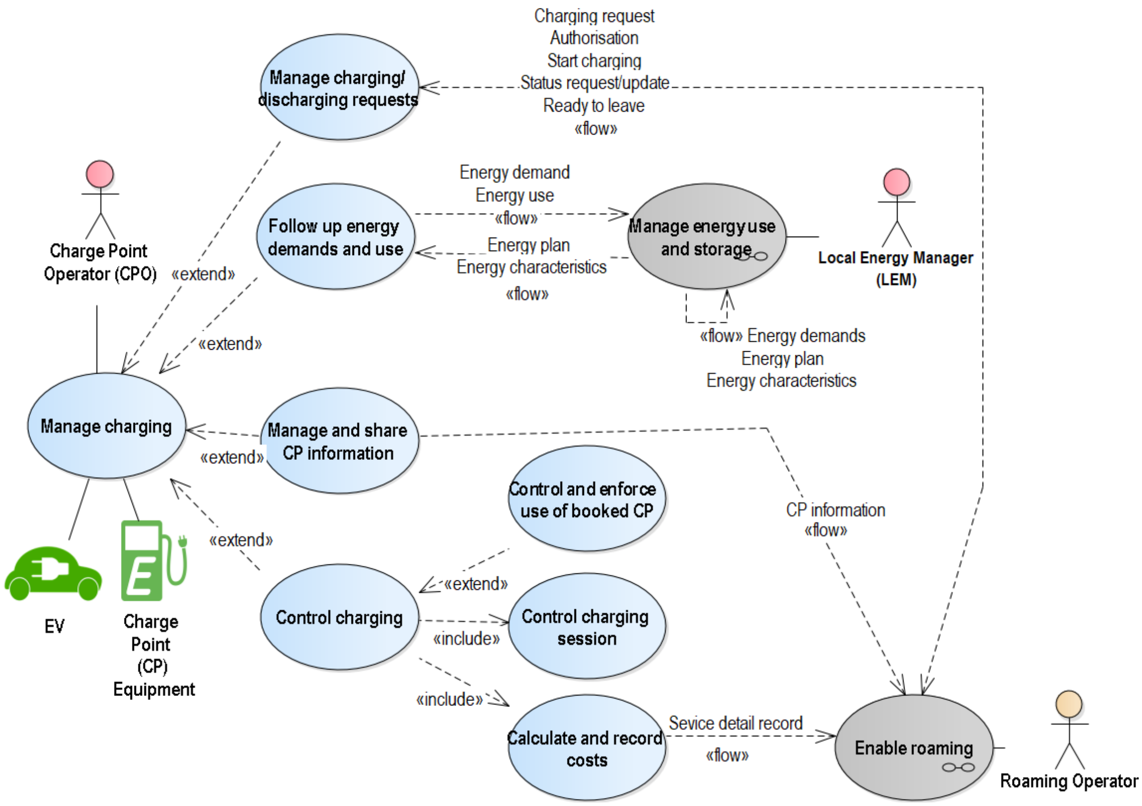

Figure 5-5 Manage charging use case

Depending on the situation, the use case will be extended by the following use cases:

<u>Manage charging/discharging requests</u>

Pre-condition/trigger event: Charge points are in operation and may be used. The CPO is ready to receive charging request.

Post-condition: A charging request is cancelled or rejected, or the charging request is authorised, and the charging is completed.

Description: This use case will manage and follow up the charging/discharging request and handle the information exchange with the EV User via the Roaming Operator:

1. An EV User has sent a new, updated, and cancelled charging request to the EMP, and the request is received via the Roaming Operator. Such requests may be sent at any time, e.g., a long time before the arrival of the electric vehicle (e.g., in case of booking of charge point) or when electric vehicles are at the charge point.

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2. The charging request is authorised or rejected.

If the charging request is authorised:

3. A start charging message indicating that the charging starts.
4. During charging, the CPO may receive and respond to status requests.
5. The CPO may also provide different types of status updates, e.g., in case of deviations.
6. If the charge point is booked for a certain time slot in advance, the following status updates may be provided:
    - Identifies the charge point to use.
    - Notification some time before the start of a booked time slot.
    - Notification some time before the charging time slot expires.
7. A ready to leave message is received when the EV User is ready to leave.

Follow up energy demands and use

Pre-condition/trigger event: After a charging request is received and handled or periodically depending on the rules.

Post-condition: This is a continuous process.

Description: In this use case

1. The CPO sends energy demands to the Local Energy Manager (LEM) based on received charging requests.
2. In return, the CPO receives a plan for optimal use of energy. The plan may be updated to reflect changes in energy availability.
3. The CPO manages the use of energy for all charge points based on the energy plan from the Local Energy Manager (LEM) and reports information about the actual energy use for the charging session.
4. The CPO receives and manages information about the energy characteristic from the Local Energy Manager (LEM). The energy characteristic describes
    - The energy mix in the distribution network over time
    - The energy prices for the energy in the distribution network over time
    - The actual energy mix in the local grid over time

Manage and share CP information

Pre-condition/trigger event: Issues that affects the statuses of the charge points and prices for charging.

Post-condition: Updated CP information is available to EV Users.

Description: This use case will

1. Manage information about the charge points managed by the CPO:
    - The characteristics of the charge services provided
    - Real-time information on current charge point availability and information on the availability of future time slot (available, booked, charging going on, etc.).
    - Real-time information on malfunctions and deviations.
    - The prices for charging and the price policy. Price reductions may for example be offered in return of desired behaviour (booking, energy demand flexibility, V2G, etc.) or extra costs may be added undesired behaviour (no booking, no flexibility, no V2G, high priority, etc.).
    - Other information of relevance to EV Users, e.g., the energy mix
2. Publish the CP information via the Roaming Operator.
5. Provide information via the charging equipment's user interface (display) on the availability of the charge point and its operative status.

Control charging

Pre-condition/trigger event: The charge point is not in use and an authorised charging can start.

Post-condition: The charging is finalised, or the charge point is blocked. More details:

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- If the charge point is booked for a certain time slot: The charging is finalised within the booked time slot, or the EV blocks the charge point when the time slot expires.
- If the charge point is not booked for a certain time slot: The charging is finalised.

Description: See details below.

Control and enforce use of booked CP

Pre-condition/trigger event: A charge request that books the charge point for a certain time slot has been received and approved.

Post-condition: The charging is finalised within the booked time slot, or the charge point is blocked when the time slot expires.

Description: This use case will

1. Book the charge point for the authorised EV Users and block it for others.
    - The duration of the blocking is decided by a policy. The blocking may for example start a short time before the booked time slot, and the blocking may be cancelled after a certain time in case of no show.
    - Just the EV User that has booked the charge point is authorised to use it while it is booked.
    - Other EV users are not able to charge at the charge point when it is booked.
2. Communicate the availability of charge point through the user interfaces of the charging equipment (display or signalling) to avoid that booked charge points are used by other EV Users.
3. Detect EVs that still are connected when the booked time slot expires. Such EVs block the charge point, and in such cases the EV User will get feedback (via the Roaming Operator) on the deviation, and the price models used may penalise such behaviour (see use case "Calculate and record costs" below).

Control charging session

Pre-condition/trigger event: The charge point is not in use or an EV with an approved charging request is connected, and charging can start.

Post-condition: Charging/discharging is finalised of it has failed.

Description: This use case controls the charging equipment and the charging/discharging of electric vehicles.

1. The operative status of the charging equipment is managed
2. The display/signalling of the charging equipment is controlled.
    - When the charge point is not in use, the display/signalling of the charging equipment is controlled to signal the availability of the charge point (information on whether it is booked or not included).
    - In case of malfunctions and deviations the display/signalling of the charging equipment is controlled to signal the availability of the charge point.
3. When an electric vehicle is connected
    - Charging/discharging is started, stopped and controlled according to the individual energy plan for the charge point.
    - The charging/discharging process is monitored
4. The charging/discharging session information is registered (to be used when the detailed service record is established). It may be carried out in many sub-sessions. The information registered is:
    - The time when the electric vehicle was connected.
    - The time when the electric vehicle was disconnected.
    - SoC at start, and after each sub-session.
    - The start and stop time for each charging/discharging sub-session.
    - The energy profile for each charging/discharging sub-session.

Calculate and record costs

Pre-condition/trigger event: A charging session is completed.

Post-condition: The costs for charging are calculated and recorded.

Description: This use case will manage the *detail service record* that includes all the information needed for billing and payment to the EMP. In this use case

1. The *detail service record* is generated and managed for finalised charging sessions based on the charging session information registered (see the "Control charging session" use case above). The detailed service records will facilitate feedback to the EV User, billing, etc. and will include
    - Connection and dis-connection time
    - SoC information at start and at end
    - The total amount of energy transferred to the EV battery
    - Details regarding the charging process, among others when charging/discharging started and stopped (once or several times) and the energy transfer profile for each sub-session.
2. Details about the energy used are also manged based on the energy characteristics received from the Local Energy Manager (LEM) (see the "Follow up energy demands and use" use case above) to facilitate statistics, analysis and assessments of gains related to smart charging (based on data received from Local Energy Manager (LEM) – see below). This includes
    - The energy mix if all energy was from the distribution grid (the baseline without smart charging)
    - The energy costs if all energy was from the distribution grid (the baseline without smart charging)
    - The average energy mix used
    - The actual energy costs
3. Information on discounts/gains for desired behaviour (e.g., charge point booking, flexible energy demand, low priority, V2G, etc.) and extra fees for non-desired behaviour (e.g., charge point blocking, request for high priority, etc.) are calculated according to pre-defined rules.

5.1.5 Manage energy use and storage

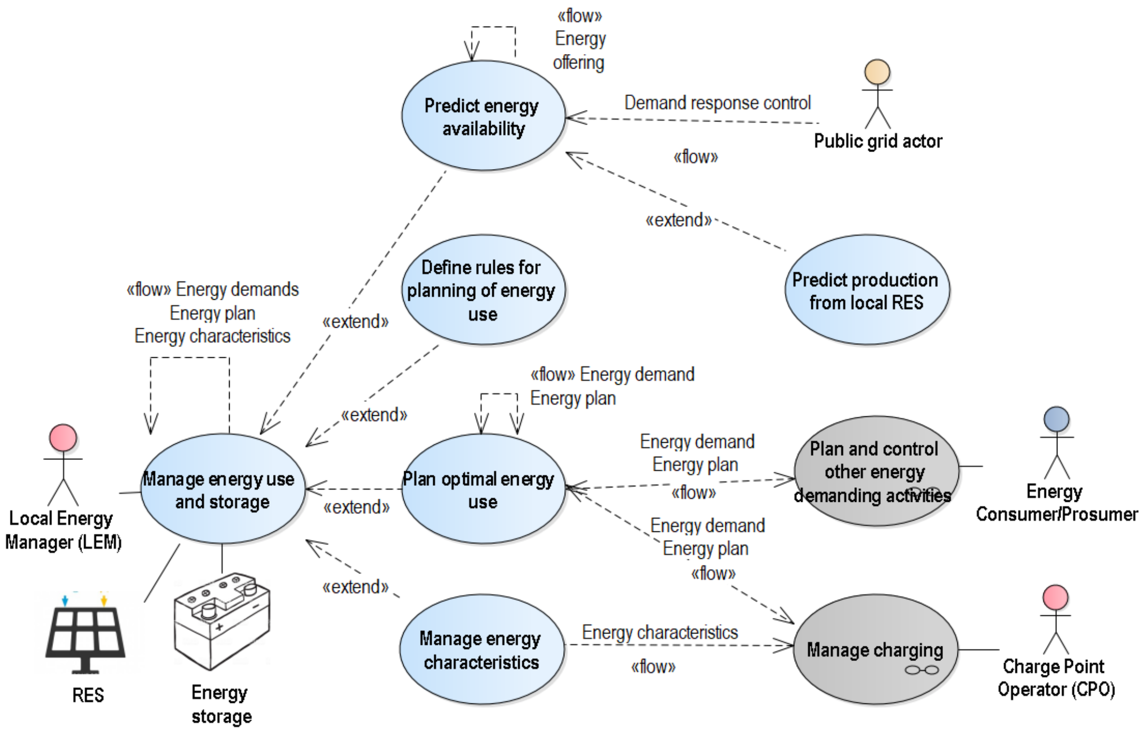

Figure 5-6 Manage energy use and storage use case

This use case addresses smart energy management in a local energy community. Such communities may be a building, a neighbourhood or an area. Local energy management is requested by CIRED (CIRED Working Group on Smart Grids 2013) and by a report commissioned by the Norwegian Water Resources and Energy Directorate (Thema Consulting Group 2018). In the context of GreenCharge, local energy management will

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.

facilitate smart and green charging with minimal grid investments through peak shaving and optimal use of energy from local renewable energy sources (RES).

Depending on the situation, the use case will be extended by the following use cases:

Predict energy availability

Pre-condition/trigger event: Any issue that may change the energy availability.

Post-condition: An overview of future energy availability is calculated, energy surplus that may be offered to linked local energy management systems included.

Description: The use case will

1. Maintain an overview of
    - Demand response input from the Public Grid Actor
    - Energy demand and energy offerings
    - Energy in local storage
    - Energy produced from local RES (see use case "Predict Production from local RES")
2. In case of a hierarchical local energy management solution, the following is also registered:
    - Energy offering from linked local energy management systems, e.g., in case of surplus production from RES in the linked local energy management systems.

Predict production from local RES

Pre-condition/trigger event: when local RES is available.

Post-condition: An overview of future energy production from local RES is updated.

Description: Provides an overview of future energy availability from local RES. The production is predicted based on input on the weather forecast.

Define rules for planning of energy use

Pre-condition/trigger event: The need for definition of update of rules for the planning of the energy use.

Post-condition: The rules for planning of energy use are defined.

Description: The rules (priorities, rules for handling of energy shortage, rules for announcement of energy flexibility, fees, etc.) must be defined in such a way that decisions on how different energy demanding activities should use energy can be automated.

Plan optimal energy use

Pre-condition/trigger event: Energy demand or predicted energy availability (detected by the "Predict energy availability" use case) is changed.

Post-condition: An energy plan for optimal use of energy with scheduling is created.

Description: In hierarchical local energy management solution, the scope of this use case may address the optimisation of the energy use at a neighbourhood level or at more limited levels. The latter may for example be the optimisation of energy use in a charging infrastructure, i.e., the future charging and/or discharging sessions at the individual charge points.

The use case will:

1. *Make an optimal plan for the use of available energy* using the rules for energy use, information about the energy availability (established above), and input on energy demands from energy demanding activities (charging sessions included). The following will be considered
    - The use of energy from stationary batteries (if such batteries are available) and from V2G (if V2G is offered) when the grid and RES capacity is limited.
    - What to do with energy from RES (self-consumption, storage in stationary batteries, or selling)

- The use of energy by energy demanding activities, charging sessions included, according to defined rules (e.g., priorities).

2. If energy availability exceeds the planned energy use in certain periods (e.g., due to high production of local renewable energy), the energy surplus can be offered (energy offering) to energy demanding activities (charging included) and/or to the local energy managements at a higher or lower level in the hierarchy. Such announcements of energy offering might result in increased energy demand (e.g., if the CPO decides to offer cheaper charging services in a period with energy surplus).

Manage energy characteristics

Pre-condition/trigger event: Trigged by the decided sampling periods.

Post-condition: The energy characteristics of the neighbourhood is updated.

Description: This use case will

1. Use reports on energy use over time to log the actual energy use for among others charging
2. Log the actual energy production from local RES over time
3. Calculate and provide information on the variation of energy properties over time such as
   - The costs for energy from the distribution grid (without use of smart energy management)
   - The grid mix in the distribution grid
   - The energy costs for the energy used (to see the effects of smart energy management)
   - The grid mix for the energy used (to see the effects of smart energy management)

   The values will depend on the energy sources used (distribution grid, local RES, storage, etc.).
4. Calculate the costs/gains related to the actual energy use/production and provide information energy users and prosumers.

5.1.6 Enable roaming

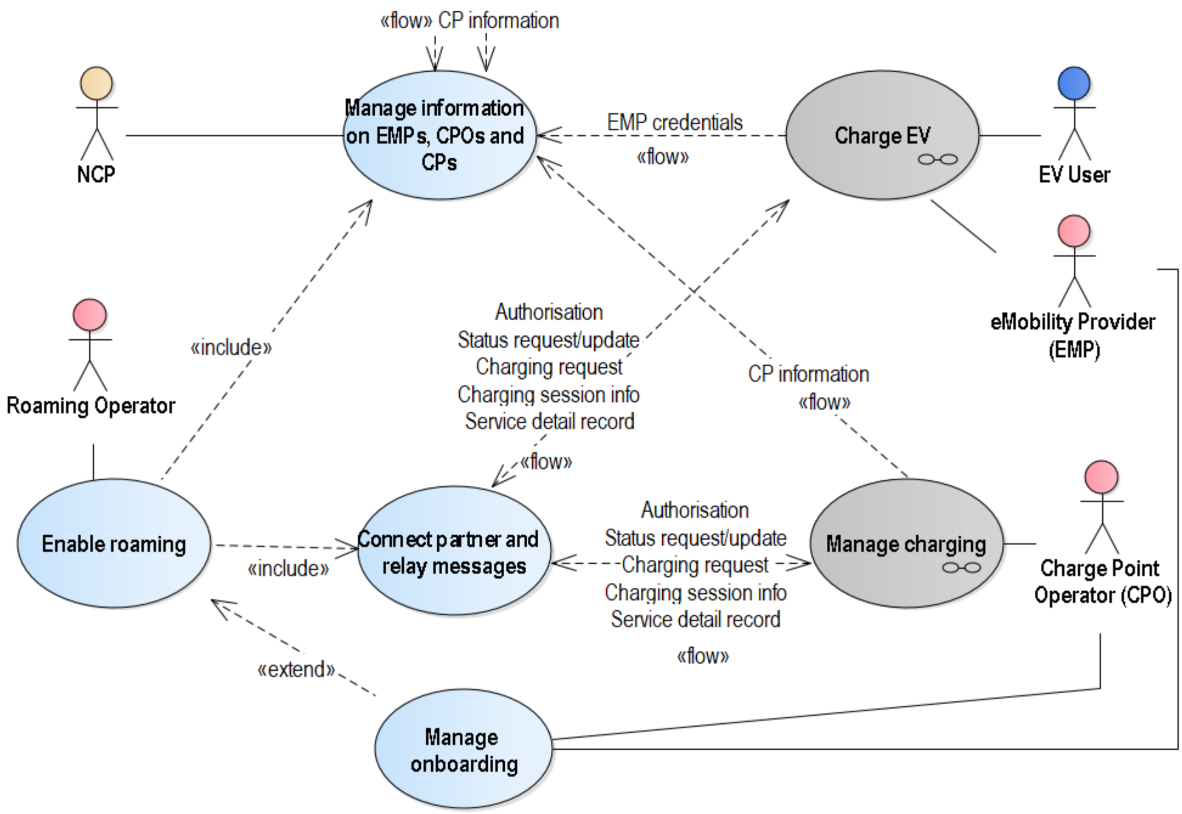

Figure 5-7 Enable roaming use case

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This use case enables roaming, i.e., information exchanges and related provisions between eMobility Providers (EMPs) and Charge point Operators (CPOs) to allow EV Users to use a single contract to access charge services provided by multiple EMPs and Charge Point Operators (CPOs) through roaming endpoints[1]. The roaming model is that an EMP enables access to charging at a charge point by talking to the CPO that manages the charge points.

In this architecture, roaming is always used in the communication between the EMP and CPO. The deployment of the Roaming Operator role may however vary:

- If there is a direct relationship between the EMP and the CPO. In this first case, the EMP actor plays the role of a Roaming Operator.
- If there is no such relationship, a third-party Roaming Operator may be used.

The roaming should support the roaming of payment as well as charging requests. Interoperability between different Roaming Operators should also be handled as described by (Ferwerda, Bayings et al. 2018).

The Enable roaming use case will include or be extended by the following use cases:

Manage onboarding

Pre-condition/trigger event: A new EMP or CPO request an agreement with the Roaming operator.

Post-condition: Onboarding completed or rejected.

Description: This use case usually includes many manual tasks. The In this use case

1. The EMP/CPO software that will communicate with the Roaming operator is tested. If it complies with the required protocol, it is approved. The protocols must cover the roaming of all new aspects required by the GreenCharge concept (charging requests with energy demands providing flexibility and advance booking included).
2. The EMP/CPO is entered into the routing directories of the Roaming operator.
3. If all tests are approved and the Roaming operator and the EMP/CPO agrees on the conditions, a contract is entered.

Manage information on EMPs, CPOs and CPs

Pre-condition/trigger event: When information is received from EMP or CPOs.

Post-condition: The information on CPs, EMPs and CPOs is updated.

Description: The use case

1. Facilitates CP information sharing. CP information can be published and updated via the Roaming Operator, and CP information may also be requested.
2. Maintains an overview of actors with a role in the provision of EV charging (roaming endpoints with contact points, etc.):
    - Roaming Operators
    - EMPs and their Roaming Operators
    - CPOs and their Roaming Operators

Connect partners and relay messages

Pre-condition/trigger event: An EV user initiates a charging session.

Post-condition: The EMP and the CPO communication has ended.

Description: The use case

1. Relays charging requests between EMPs and CPOs. The requests may include advance booking of charge points, energy requests, charging flexibility, and V2G flexibility

[1] IEC 63119 pre-release version, 2019

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. Relays messages related to the charging requests and the related charging sessions. This includes:
    - Authorisations
    - Status requests and status updates
    - Charging session information exchange
    - Service detail record exchange

5.1.7 Plan and control other energy demanding activities

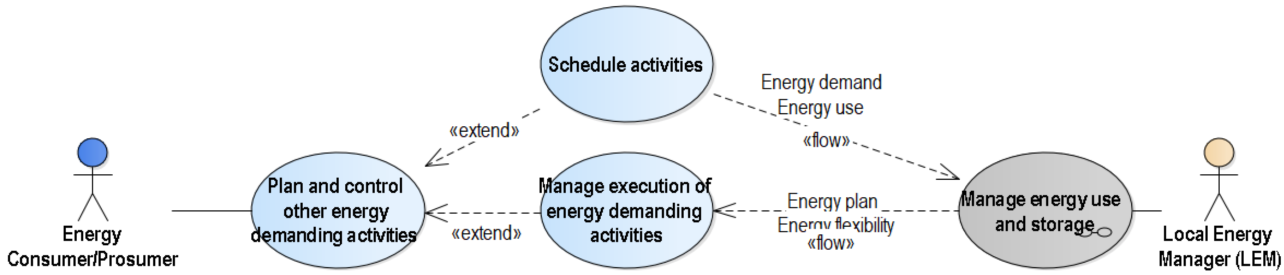

Figure 5-8 Plan and control other energy demanding activities use case

Depending on the situation, the use case will be extended by the following use cases.

Schedule activities

Pre-condition/trigger event: an energy consumer/prosumer wants to schedule an energy demanding activity.

Post-condition: The resulting energy demand (with flexibility included) is provided to the Local Energy Manager.

Description: The consumer schedules activities that require energy. This scheduling may also provide flexibility with respect to when the activities are to be accomplished.

Manage execution of energy demanding activities

Pre-condition/trigger event: when an energy plan with energy flexibility is received from the Local Energy Manager.

Post-condition: The energy demanding activities are executed according to the plan.

Description: The energy demanding activities will start and stop according to the plan provided by the Local Energy Manager.

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5.2 Use case to service mapping model

To ensure the necessary openness, the architecture is modelled as a set of digital services collaborating through message exchange. The mapping of the implementation of these services onto underpinning systems is left to each deployment, as illustrated in Figure 14. The services implement the GreenCharge solution described by the use cases depicted in Figure 6

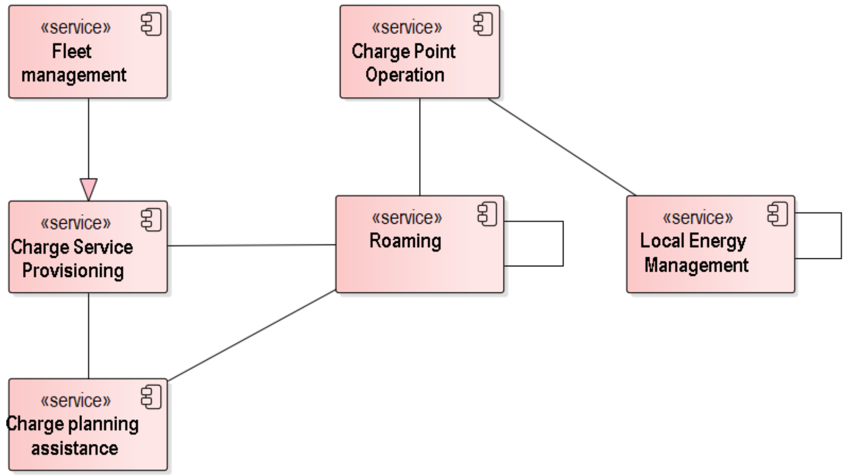

Figure 5-9 Services in the GreenCharge solution

The services are:

- *Charge service provisioning:* eMobility Providers (EMPs) or a third party (that for example might be a MaaS operator, a Fleet Operators and others) provides a charge service to EV Users as a stand-alone service or integrated with other services (e.g., MaaS, car sharing, etc.).
- *Fleet management:* Fleet operators (FO) operate an EV fleet that needs charging.
- *Charge point operation*. Charge Point Operators (CPOs) receives the charging requests and controls the actual charging. The aim is optimal charging adapted to the EV Users' needs and the energy availability.
- *Local energy management*: Local Energy Managers (LEMs) provide smart energy management for optimal use of energy. The use of energy in charging is adapted to both the energy availability and to other energy demands. This service may collaborate with other similar services in a hierarchy of local energy Management services.
- *Charge planning assistance*. The EV User is supported to facilitate easy and if possible automated charge planning. The charge points are selected, and charging requests are established based on the charging needs (amount of energy needed, time schedule, etc.)
- *Roaming*: Roaming Operators (ROs) enable roaming services. The roaming service implements the communication between roaming endpoints.

Figure 15 illustrates the mapping between the overall use cases defined in section 5.1 and the services Figure 14.

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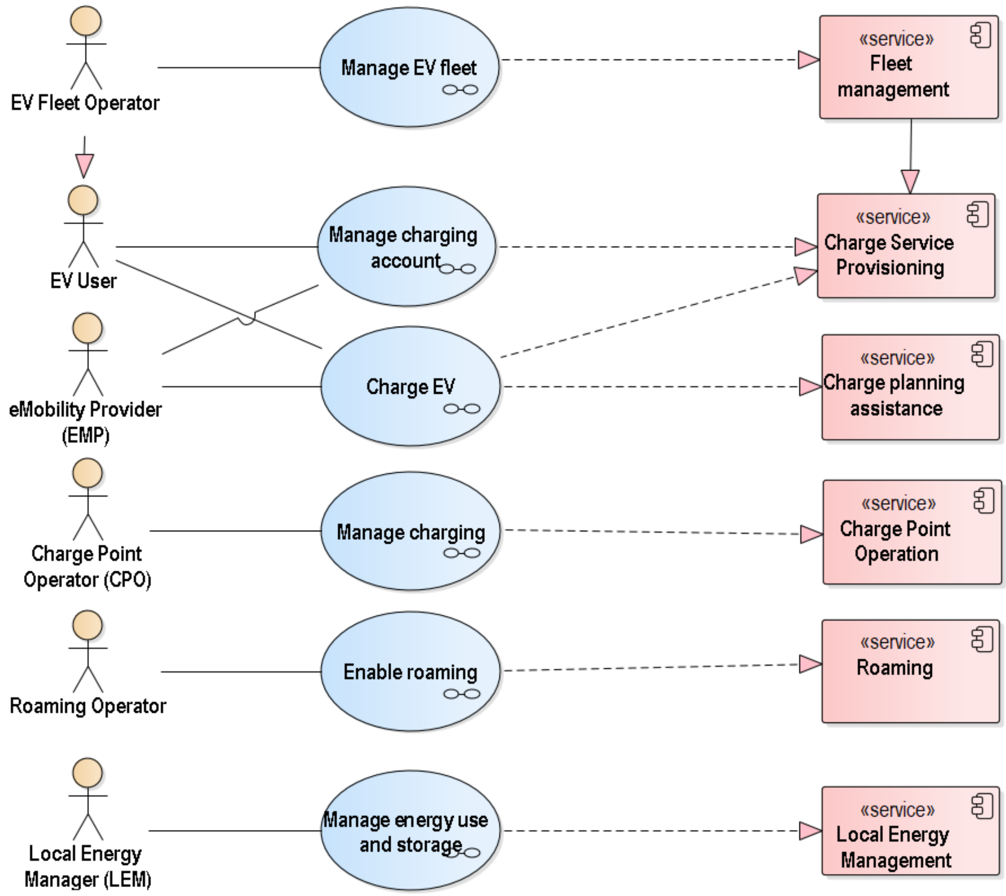

Figure 5-10 Use case – service mapping model

Use of this model as a blueprint in system architecture descriptions: The services of relevance should be identified based on the use cases to be addressed.

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5.3 Environment model

The environment model in Figure 16 provides an overview of the GreenCharge solution and its environments.

The interfaces needed between the GreenCharge solution and other system components in the environment are identified.

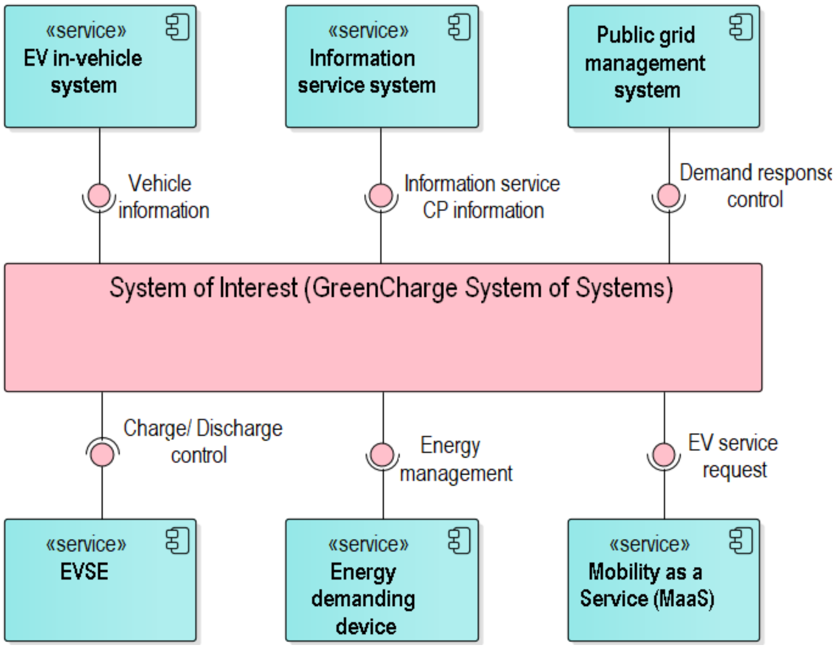

Figure 5-11 Environment model

The environment of the GreenCharge solution is depicted in Figure 16. The following other system components are not further specified by this reference architecture description:

- *EV in-vehicle system.* This is the system(s) provided by the electric vehicle (EV) manufacturer.
- *Information system*: Several information services are of relevance to the System of Interest. The services may have various interfaces and may be provides by different actors. The information provided may for example be charge point information, meteorological information, information on energy prices and tariffs, POI information, etc. European Regulation EU Reg 2017/1926 requires that parts of the information listed above is shared. CP information is provided via National Contact Points (NCPs) or other channels.
- *Public grid management system.* This system does demand response control.
- *Electric Vehicle Supply Equipment (EVSE).* The equipment delivers electric energy to electric vehicles connected to charge points.
- *Energy demanding devices.* This may be any kind of devices, and they may communicate with the GreenCharge solution through standardised or proprietary interfaces.
- *Mobility as a Service management system.* Such systems may communicate with EV Fleet Operators offering mobility services.

The interfaces towards the external components are addressed in section 7.2.

Use of this model as a blueprint in system architecture descriptions: The environment of relevance should be identified.

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

6 Requirement view

This chapter describes generic requirements linked to the implementation of the system of interest described in Chapter 3. We use the goals in the motivation diagrams in Chapter 4.2 (summarized in section 1.1) to define the overall requirement. The overall requirements are derived from one or more goals. In addition, more detailed requirements originate from the use case model in section 5.1; needs from the pilots in WP2; needs regarding business models from WP3; intermediate evaluation results from deliverable D5.4; and aspects from other sources like the DOA.

The requirements are organised in the following categories:

- Local Energy Management requirements (EM)
- Smart Charging requirements (SC)
- EV Fleet Management requirements (FM)
- Roaming requirements (RO)
- Generic requirements (GR)
- Interface requirements (IR)
- Public Policy (PP)

The requirements have identifiers (IDs) composed of the associated topic (EM, SC, FM, RO or PP) and a sequence number (e.g., SC1).

Note that since this document is a reference architecture description, a complete set of requirements specific to individual realisations (e.g., the design of the user interface) is not addressed. *The focus is on the minimal set of requirements that is principal for the realisation of the GreenCharge concept*, such as requirements that affects the information exchange between system components and arrange for smart and green charging.

Tables are used to decompose the overall requirements into more detailed requirements. For each detailed requirement the following issues are described:

- *ID*. The category and number of the overall requirement and a sequence number (e.g., SC1.1)
- *Description*. Defines the requirement
- *Source*. Indicates where the input on the detailed requirement originates from. This may be a use cases in section 5.1 (which are aggregated use cases based on individual use cases from the pilots), requirements defined by the GreenCharge pilots, etc.
- *Aspect*. Architectural issues affected by the requirement, e.g., functional issues regarding the GreenCharge solution (related to one or more of the use cases), the environment of the GreenCharge solution, or a part of this reference architecture (any view/model).

Use of this view: The purpose of the requirements is twofold:

- Guide the design of this reference architecture description.
- Guide the design of system architecture descriptions and solutions that use this reference architecture as a blueprint.

For the latter, the overall requirements of relevance should be identified (see diagrams and tables below). The detailed requirements associated with these overall requirements as well as the generic requirements and the requirements to the interfaces should be considered and prioritised. Additional requirements addressing detailed functionality and other issues specific to the system addressed should be added.

The *aspect* column in the table below refer to the aspects of relevance.

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

6.1 Smart Charging (SC) requirements

Figure 17 shows the overall requirements derived from the goals in the Smart Charging category.

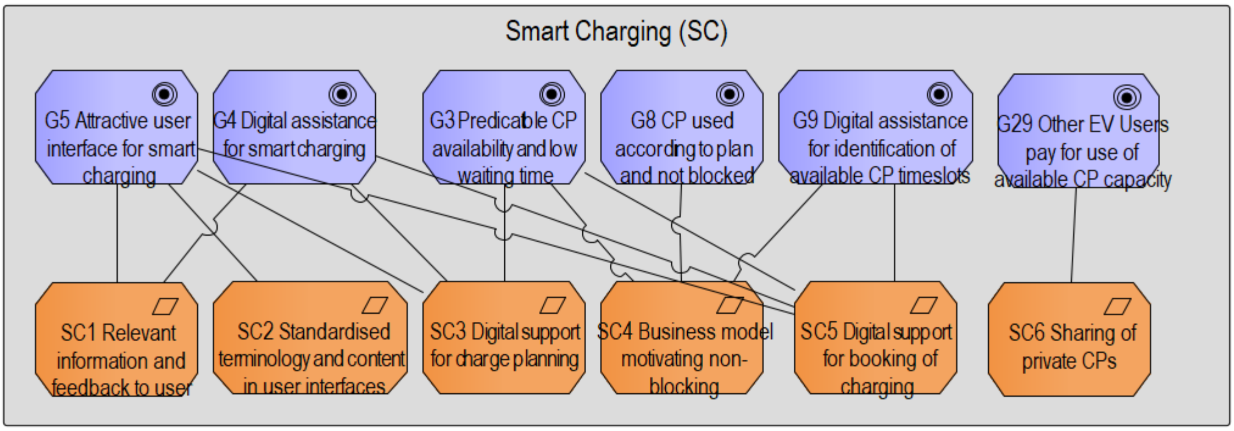

Figure 6-1 Overall requirements for Smart Charging (SC)

The overall requirements are further detailed as listed in the tables below.

SC1 Relevant information and feedback to user			
ID	**Description**	**Source**	**Aspect**
SC1.1	For a booking request, feedback to the user is needed when the electric vehicle cannot be charged to the target State of Charge (SoC) at the planned end time.	Pilot (BRE)	• Functionality • Use case model • Information model • System component and interface model • Collaboration model
SC1.2	EV Users should get information on prices for charge services as a part of the information about charge points (in case of pay per use business model).	Use case in 5.1.2: • Find CP	• Functionality • Information model • System component and interface model • Collaboration model
SC1.3	If the EV is assigned a specific charge point or, or if some charge points cannot be used since they are pre-booked by others, the EV User must get information on this.	Use case in 5.1.2: • Monitor charging • Updated based on initial evaluation (deliverable D5.4)	• Functionality • Information model • System component and interface model • Collaboration model
SC1.4	The EV User must on request get notifications before the start of a booked charging period and when the charging is finished.	Use case in 5.1.2: • Monitor charging Use cases in 5.1.4: • Manage charging/ discharging requests • Follow up energy demands and use • Control charging process	• Functionality • Information model • System component and interface model • Collaboration model
SC1.5	EV Users should be able to request status information regarding the charging/discharging.		
SC1.6	It must be possible to request information about the charging with respect to energy use, grid mix and savings.		• Functionality • Information model • System component and interface model • Collaboration model
SC1.7	The system must record data that supports statistics and feedback to the EV User.		
SC1.8	The energy management system must provide data that supports the calculation of savings and improvements (e.g., in the grid mix)	Use cases in 5.1.5: • Manage energy characteristics	• Information model • System component and interface model • Collaboration model
SC1.9	The EV User must get information on malfunctions and deviations.	Use case in 5.1.2: • Monitor charging	• Information model

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		Use cases in 5.1.4: • Control charging process	• System component and interface model • Collaboration model
SC1.10	EV Users must get detailed billing information.	Use case in 5.1.2: • Billing Use cases in 5.1.4: • Calculate and record costs	• Information model • System component and interface model • Collaboration model
SC1.11	A detailed service record with all information needed to document the billing must be established and recorded by the system.		

SC2 Standardised terminology and content in user interfaces			
ID	**Description**	**Source**	**Aspect**
SC2.2	The terminology established in this document must be used as a common terminology.		• Domain concepts • Information model • Collaboration model
SC2.2	The common terminology must be used when the charging request is specified and when of default values are defined. This includes charge point booking, energy booking, charging flexibility and V2G.	Use case in 5.1.1: • Manage charging account Use case in 5.1.2: • Find CP • Authorise charging and define constraints	• Functionality
SC2.3	The common terminology must be used when the EV User is supported in the identification of the charge point to use	Use case in 5.1.2: • Find CP	• Functionality
SC2.4	The common terminology must be used in feedback on the charging/discharging and when information about the charging (with respect to energy use, grid mix and savings) and billing information is provided.	Use case in 5.1.2: • Manage charging progress status • Billing	• Functionality

SC3 Digital support for charge planning			
ID	**Description**	**Source**	**Aspect**
SC3.1	The SoC of the batteries should be provided to the GreenCharge system.	Pilot (BCN)	• Functionality • Information model • System component and interface model • Collaboration model
SC3.2	The priority charging should adapt to available energy in real time.	Pilot (OSL) Use cases in 5.1.4: • Manage charging	• Functionality • Information model • System component and interface model • Collaboration model
SC3.3	The EV User must be authorised before the charging can be booked/used.	Pilot (OSL) Use case in 5.1.1: • Manage charging account Use case in 5.1.2: • Find CP • Authorise charging and define constraints Use case in 5.1.6: • Connect partners and relay messages	• Functionality • Information model • System component and interface model • Collaboration model
SC3.4	Roaming should facilitate charge planning across EMPs/CPOs.		
SC3.5	EV User should get the charge point access confirmed before the detailed charge planning starts (to avoid the definition of charging requests that cannot be accepted).		
SC3.6	The system must support the EV User in the localisation of relevant charge stations.	Use case in 5.1.2: • Find CP Use cases in 5.1.4:	• Functionality • Information model

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		• Manage and share CP information	• System component and interface model • Collaboration model
SC3.7	The system must facilitate use of default values when the charging request is defined.	Use case in 5.1.1: • Manage charging account Use case in 5.1.2: • Find CP • Authorise charging and define constraints Use cases in 5.1.4: • Manage charging/ discharging requests	• Functionality • Information model • System component and interface model • Collaboration model
SC3.8	It must be possible to constrain the flexibility of charging in accordance with user needs.		

SC4 Business model motivating non-blocking			
ID	**Description**	**Source**	**Aspect**
SC4.1	Business and price model must define fees for charge point blockings to avoid waiting time.	Use cases in 5.1.4: • Control use of CPs and enforce bookings Goal from DOA KPI GC5.5 in D5.4 Updated based on initial evaluation (deliverable D5.4)	•
SC4.2	The technology must facilitate the use of price models that prohibit blocking		•
SC4.3	Bookings must be enforced. EV Users that block the charge point after the end of the booked period must be adequately penalized.	Use cases in 5.1.4: • Control use of CPs and enforce bookings	• Functionality • Information model • System component and interface model • Collaboration model
SC4.4	Blocking of charge points by non-charging vehicles must be detected to facilitate enforcement.		
SC4.5	Technology must support business and price models aiming for high utilization of charge points.	Goal from DOA KPI GC5.3 in D5.4 Updated based on initial evaluation (deliverable D5.4)	

SC5 Digital support for booking of charging			
ID	**Description**	**Source**	**Aspect**
SC5.1	The EV User must get support in finding the charge point to book and in the booking of charging.	Use case in 5.1.2: • Find C • Authorise charging and define constraints Use cases in 5.1.4: • Manage charging/ discharging requests	• Functionality • Information model • System component and interface model • Collaboration model
SC5.2	EV Users that have booked a charge point should on request be notified some time before the booking period starts.	Use case in 5.1.2: • Monitor charging Use cases in 5.1.4: • Manage charging/ discharging requests	• Functionality • Information model • System component and interface model • Collaboration model
SC5.3	When a charge point is booked, this should be communicated by the user interface of the charging equipment, and it must be impossible for EV Users that have not booked the charge point to charge at charge point.	Use cases in 5.1.4: • Control use of CPs and enforce bookings	• Functionality • Information model • System component and interface model • Collaboration model

SC6 Shared private CPs

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.

ID	Description	Source	Aspect
SC6.1	Solutions for CP sharing must support the sharing of CP information through channels used by potential customers. Information on CP availability must be included.	Use cases in 5.1.4: • Manage and share CP information Updated based on initial evaluation (deliverable D5.4)	• Functionality • Information model • System component and interface model • Collaboration model
SC6.2	Solutions for CP sharing must support roaming to be attractive to more users.	Use case in 5.1.2: • Find CP • Authorise charging and define constraints • Billing Use cases in 5.1.4: • Manage charging/discharging requests • Control charging process Use case in 5.1.6: • Connect partners and relay messages Updated based on initial evaluation (deliverable D5.4)	• Functionality • Information model • System component and interface model • Collaboration model
SC6.3	Solutions for CP sharing must support authorisation of EV Users and charge management that starts and stops charging provided that the EV User is authorised.		•
SC6.4	Solutions for CP sharing must provide standardised interfaces that allow applications from third parties to support EV User in the use of shared charge points.		•

6.2 Local Energy Management (EM) requirements

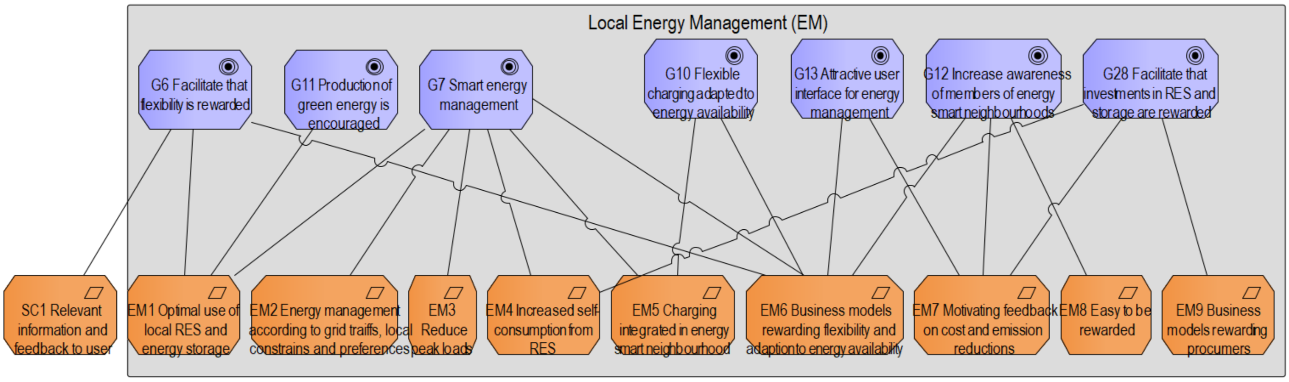

Figure 6-2 Overall requirements for Local Energy Management (EM)

The following overall requirement is not further detailed since it is addressed by EM2 and EM3:

- EM4 Increased self-consumption from RES

The overall requirements are further detailed as listed in the tables below.

EM1 Optimal use of local RES and energy storage			
ID	**Description**	**Source**	**Aspect**
EM1.1	The system must receive information of future energy demands (booked or predicted) to be able to have an overview of the future energy flexibility.	Use cases in 5.1.4: • Follow up energy demands and use Use cases in 5.1.5:	• Functionality • Information model • System component and interface model • Collaboration model
EM1.2	The system must obtain information of future energy availability from the distribution grid, local RES, local storage and V2G flexibility.		

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EM1.3	Based on predicted energy availability, the optimal use of the different energy sources (RES and storage included) must be planned, and energy consuming devices and batteries must be controlled accordingly.	• Predict energy availability • Plan optimal energy use	
EM1.4	The energy management system must be able to interact with other energy management systems in a hierarchy of such systems to facilitate optimal use of energy.		
EM1.5	The system must predict the energy needs and the local production of energy from RES and use the outcome of these predictions to plan the use of energy from local RES.	Goal from DOA KPI GC5.9 in D5.4 Updated based on initial evaluation (deliverable D5.4)	

EM2 Energy management according to grid tariffs, local constraints and preferences			
ID	**Description**	**Source**	**Aspect**
EM2.1	The system must plan energy use according to predefined rules.	Use cases in 5.1.5: • Define rules for planning of energy use • Plan optimal energy use	• Functionality • Information model • System component and interface model • Collaboration model
EM2.2	It must be possible to define rules regarding the use of energy from local RES.		

EM3 Reduced peak loads			
ID	**Description**	**Source**	**Aspect**
EM3.1	The system must plan and manage optimal energy use. The energy use must be distributed over time to avoid peak loads and to maximise utilisation of locally produced energy and minimise cost. It must be possible to configure the balancing between possibly conflicting goals.	Use cases in 5.1.5: • Predict energy availability • Plan optimal use of energy	• Functionality • Information model • System component and interface model • Collaboration model
EM3.2	The system must predict future loads and energy flexibility through input on energy demands.		
EM3.3	The energy management system must be able to interact with other energy management systems in a hierarchy of such systems to reduce peak loads.		
EM3.4	The system must reduce the power peaks compared to a solution where no peak reduction measures are taken	Goal from DOA KPI GC5.10 in D5.4 Updated based on initial evaluation (deliverable D5.4)	

EM5 Charging integrated in energy smart neighbourhood			
ID	**Description**	**Source**	**Aspect**
EM5.1	A hierarchical organisation of the energy management system must be possible. The energy management may for example be carried out at building level, charging hub level or e-bike station level. These energy management sub-systems must however collaborate to become a full-fledged GreenCharge system.	Pilots (BCN) Use cases in 5.1.5: • Plan optimal use of energy Updated based on initial evaluation (deliverable D5.4)	• Functionality • Information model • System component and interface model • Collaboration model

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EM5.2	The energy management must take all loads in the neighbourhood into account when the energy use is planned.	Use cases in 5.1.5: • Plan optimal use of energy	• Functionality • Information model • System component and interface model • Collaboration model
EM5.3	The integration of charging into ESNs as well as other energy use, energy storage, and energy production must be standardised. With standardised integration, the need for careful investigations, planning, and customization will be reduces, and the ESN realisation will become more feasible.	Intermediate evaluation (deliverable D5.4)	• Functionality • Information model • System component and interface model • Collaboration model
EM5.4	The charge point equipment used in the ESN must be designed for remote control from a third party like the local energy management systems. It must be possible to override less advanced built-in control mechanisms to start and stop individual charging and to charge with different speeds, adapted to both the energy availability and the needs of the EV user.	Intermediate evaluation (deliverable D5.4)	• Functionality • Information model • System component and interface model • Collaboration model
EM5.5	It must be possible to use second life EV batteries as stationary energy storage in the ESN. To make such re-use safe, the batteries should be provided by an existing OEM or a contracted supplier. This market must evolve to make use of such batteries viable.	Intermediate evaluation (deliverable D5.4)	•
EM5.6	Simple/normal energy management (e.g., even distribution of energy among EVs) must be possible if advanced energy management (see EM5.7) cannot be provided.	Intermediate evaluation (deliverable D5.4)	•
EM5.7	Advanced energy management taking predictions and user demands must be taken into account.	Intermediate evaluation (deliverable D5.4)	• Functionality • Information model • System component and interface model • Collaboration model

EM6 Business models rewarding flexibility and adaption to energy availability			
ID	**Description**	**Source**	**Aspect**
EM6.1	A price model must define the prices for priority and how flexibility should be rewarded (e.g., depending on the degree of flexibility provided).	D3.2	• Functionality • Information model • System component and interface model • Collaboration model
EM6.2	Business and price models should provide incentives for desired behaviour. Priority requests should be penalised (e.g., extra fee per Kw or for a full charging cycle) and V2G should be rewarded.	D3.2 Goal from DOA KPI GC5.3 in D5.4 Updated based on intermediate evaluation (deliverable D5.4)	
EM6.3	The technology should facilitate the use of business and price models encouraging desired behaviour		

EM7 Motivating feedback on cost and emission reduction			
ID	**Description**	**Source**	**Aspect**

EM7.1	The system must collect and manage data that facilitate the provision of information to the EV Users.	Pilot (OSL) Use cases in 5.1.5: • Manage energy characteristics Use cases in 5.1.4: • Manage charging/discharging requests • Follow up energy demands and use	• Functionality • Information model • System component and interface model • Collaboration model
EM7.2	The EV User should get information on the energy amount transferred to the battery of the electric vehicle.		
EM7.3	The EV User and the Charge Point Operators (CPO) should get feedback/statistics on the local energy mix during charging compared with the energy mix in the distribution network.		
EM7.4	The Charge Point Operators (CPO) should get feedback/statistics on savings in energy costs due to the smart energy management.		
EM7.5	EV Users should get information on prices showing the cost reductions they will get with desired behaviour (booking, flexibility, V2G, etc.)	Use cases in 5.1.4: • Manage and share CP information Use case in 5.1.2: • Find CP	

EM8 Easy to be rewarded			
ID	**Description**	**Source**	**Aspect**
EM8.1	The prices (rewarding desired behaviour) and the business models must be easy to understand and easy to adapt to.	Use cases in 5.1.4: • Manage and share CP information Use case in 5.1.2: • Find CP	• Functionality • Information model • System component and interface model • Collaboration model
EM8.2	The EV User should be supported when default values and charging requests are defined to make smart and green charging easy.	Use case in 5.1.1: • Manage charging account Use case in 5.1.2: • Find CP • Authorise charging and define constraints	

EM9 Business models rewarding prosumers			
ID	**Description**	**Source**	**Aspect**
EM9.1	The amount of energy provided by RES must be recorded	Use cases in 5.1.5: • Predict energy availability	• Functionality • Information model • System component and interface model • Collaboration model
EM9.2	There must be a price model for prosumers	D3.2	

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6.3 EV Fleet Management (FM) requirements

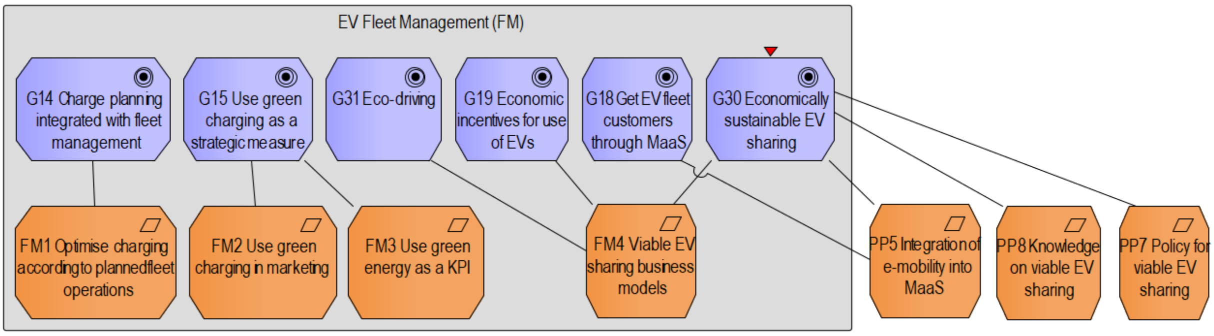

Figure 6-3 Overall requirements for EV Fleet Management (FM)

The following overall requirements are outside the scope of this reference architecture description:

- FM2 Use green charging in marketing
- FM3 Use green energy as a KPI (this is a part of the fleet management in general).

As illustrated in Figure 6, the EV Fleet Operator is a specialisation of the EV User. Thus, several of the requirements provided on Smart charging may also be relevant to the EV fleet operator. These requirements are not repeated here.

The FM1 overall requirement is further detailed as listed in the tables below.

FM1 Optimise charging according to planned fleet operations			
ID	**Description**	**Source**	**Aspect**
FM1.1	The SoC of the batteries should be provided to the fleet management system during EV operation.	Pilots (BCN D1, BRE D2) Use cases in 5.1.3: • Manage fleet resources • Monitor and manage EV information	• Functio-nality
FM1.2	The geo-location of the vehicles should be provided to the fleet management system.		

The FM4 overall requirement is further detailed as listed in the tables below.

FM4 Viable EV sharing business models			
ID	**Description**	**Source**	**Aspect**
FM4.1	Data on the use of the eco-driving mode should be provided to the fleet management system during EV operation.	Pilots (BCN D1, BRE D2) Use cases in 5.1.3: • Manage fleet resources • Monitor and manage EV information	• Functio-nality
FM4.2	Business models should define a discount for eco-driving.		

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

6.4 Roaming Management (RM) requirements

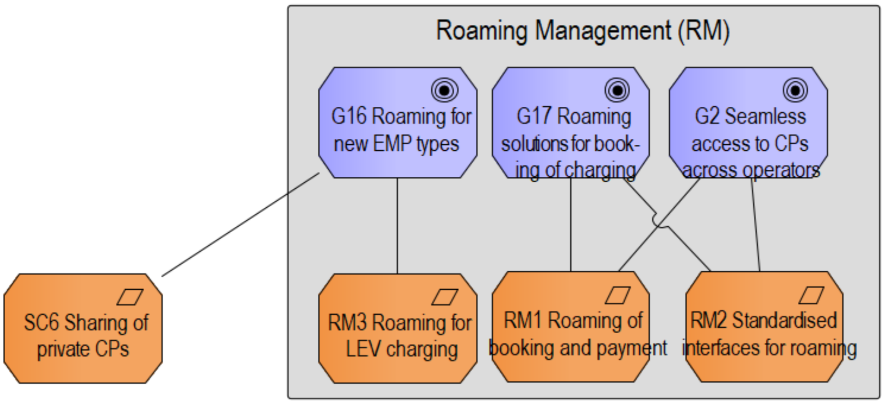

Figure 6-4 Overall requirements for Roaming Management (RM)

RM1 Roaming of booking and payment			
ID	**Description**	**Source**	**Aspect**
RM1.1	Roaming must facilitate booking of charging and energy (long time in advance) across eMobility Providers (EMPs)/Charge Point Operators (CPOs).	Use case in 5.1.2: • Find CP • Authorise charging and define constraints • Monitor charging • Analyse charging • Billing Use cases in 5.1.4: • Manage charging/discharging request • Manage and share CP information • Control charging process Use case in 5.1.6: • Connect partners and relay messages	• Functionality • Information model • System component and interface model • Collaboration model

RM2 Standardised interfaces for roaming			
ID	**Description**	**Source**	**Aspect**
RM2.1	The interfaces needed for roaming must be standardised and support all relevant services related to smart and green charging.	Use case in 5.1.6: Enable roaming	• Functionality • Information model • System component and interface model • Collaboration model

RM3 Roaming for light EV (LEV) charging			
ID	**Description**	**Source**	**Aspect**
RM3.1	The same roaming principles should be followed for all types of electric vehicle charging.	Use case in 5.1.2: Charge EV Use cases in 5.1.4: Manage charging Use case in 5.1.6: Enable roaming	• Functionality • Information model • System component and interface model • Collaboration model
RM3.2	EV Users with a subscription should be able to use that subscription for charging of all their electric vehicles, light electric vehicles included.		

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6.5 Generic requirements (GR)

GR: Generic requirements from pilots (that are either applicable to several/ all aspects above, or are not directly related to a specific aspect from above):			
ID	**Description**	**Source**	**Aspect**
GR1	Safety: Safety will be paramount to prevent injuries.	Pilot (BCN)	•
GR2	Openness: Non-proprietary solutions for HW and SW will be preferred to avoid dependencies with third parties not participating in the project and to assure access to all the features provided by any device.	Pilot (BCN) Best practice	• Information model • System component and interface model • Collaboration model
GR3	Multi-language support: The user interfaces of the App for EV Users and the backend systems for system administrators will support multi-languages.	Pilot (BCN)	• Functionality
GR4	Availability: The solution must have a high and well-defined availability goal. This means that the systems components and the communication between them must function as required and prevent disruptions due to failures and system upgrades.	Best practice	• Information model • System component and interface model • Collaboration model • Deployment view
GR5	Availability: Procedures and responsibilities that ensure availability must be defined.	Best practice	
GR6	Security: Information security in general should be according to ISO/IEC 27002 Information technology — Security techniques — Code of practice for information security controls	Standard	• Functionality • Information model • System component and interface model • Collaboration model • Deployment view
GR7	Security: Information security related to roaming and payment should be according to IEC 27001 Information security management systems	Standards	
GR8	Privacy: the system must ensure the privacy of the EV Users. The solution must be compliant with GDPR.	European regulation	
GR9	Security – access control: The access to the systems involved must be secured through identification, authentication and authorisation of users.	Best practice	
GR10	Security – authentication of systems: The systems involved in communication must be authorised.	Best practice	
GR11	Security – data integrity: The integrity of the data exchanged between systems must be ensured,	Best practice	
GR12	Security – non-repudiation: It must be ensured that the one part on a transaction cannot deny having received the transaction.	Best practice	
GR13	Security – information content protection: The information content in transactions should be protected through cryptography whenever this is relevant.	Best practice	
GR14	Scalability: The solutions should work when full emobility of the transport sector is achieved, i.e., when all vehicles are electric, and the charging infrastructure covers all charging needs.	Best practice	• Information model • System component and interface model • Collaboration model • Deployment view

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6.6 Interfaces requirement (IR)

The requirements regarding the interfaces between the services in section 5.2 and 5.3 are defined below.

IR Interface requirements			
ID	**Description**	**Source**	**Aspect**
IR1	Standard: Compliance with widely adopted standard solution, protocols and interfaces will be considered in the choice to facilitate future interoperability of the solutions developed.	Pilot (BCN)	• System component and interface model • Collaboration model
IR2	Vehicle information should be obtained from the electric vehicle by means of the OBD2 standard. This also include data on the State of Charge (SoC) when such information is openly available via this interface.	Standard	• System component and interface model • Collaboration model
IR3	For Charge Service Provisioning: Charging requests must provide necessary information for smart charging.	Section 6.1	• System component and interface model • Collaboration model
IR4	For interactions with Local Energy Management: Information needed for optimal energy use by individual energy demanding activities must be exchanged.	Section 6.2	• System component and interface model • Collaboration model
IR5	For interaction between electric vehicle charging and Charge point operation: The interface between the charging equipment (EVSE) and the charge managements must be according to the Open Charge Point Protocol (OCPP 2.0).	Standard	• System component and interface model • Collaboration model
IR6	For interactions with the in-vehicle system when charging/discharging (V2G); The interface must be according to the ISO 15118 Road vehicles – Vehicle to grid communication interface.	Section 5.3 Standard	• System component and interface model • Collaboration model
IR7	For interaction with Roaming: The interface used towards roaming should be according to IEC 63119 and IEC 63119-1 ED1 – Information exchange for Electric Vehicle charging roaming service (when the standard is ready).	Standard	• System component and interface model • Collaboration model
IR8	For publication of CP information: A standardised interface for the sharing of CP information should be used. Information showing when the CP is booked and available must be shared.	Oslo D2	• System component and interface model • Collaboration model
IR9	For charge planning: A standardised interface for charge planning is needed. The interface must define a charging request in such a way that the smart energy management can be informed about the energy demand.	Oslo D1 Barcelona D2	• System component and interface model • Collaboration model

6.7 Public policy (PP)

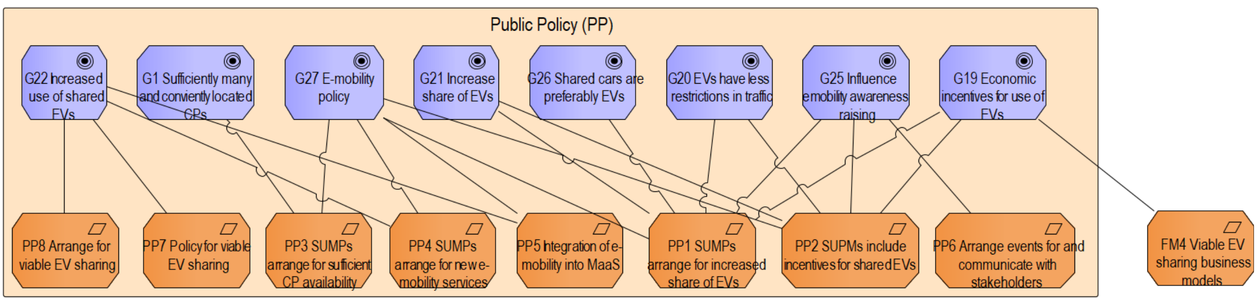

Figure 6-5 Overall requirements for Public Policy (PP)

The requirements regarding transport policies will not affect the digital solution and are not further decomposed to detailed requirements in this deliverable. The requirements are input to the work on SIMPs WP7.

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

7 Component view

This view addresses how the services identified in the context view, collaborate and interact. The view includes

- System information model defining the information exchanged.
- System component and interface model identifying the interfaces used for communication.
- System collaboration model defining how the services interact.

7.1 System Information model

The information model is divided into sub-models, and an overview of the sub-models and the information classes they contain is provided in Figure 22.

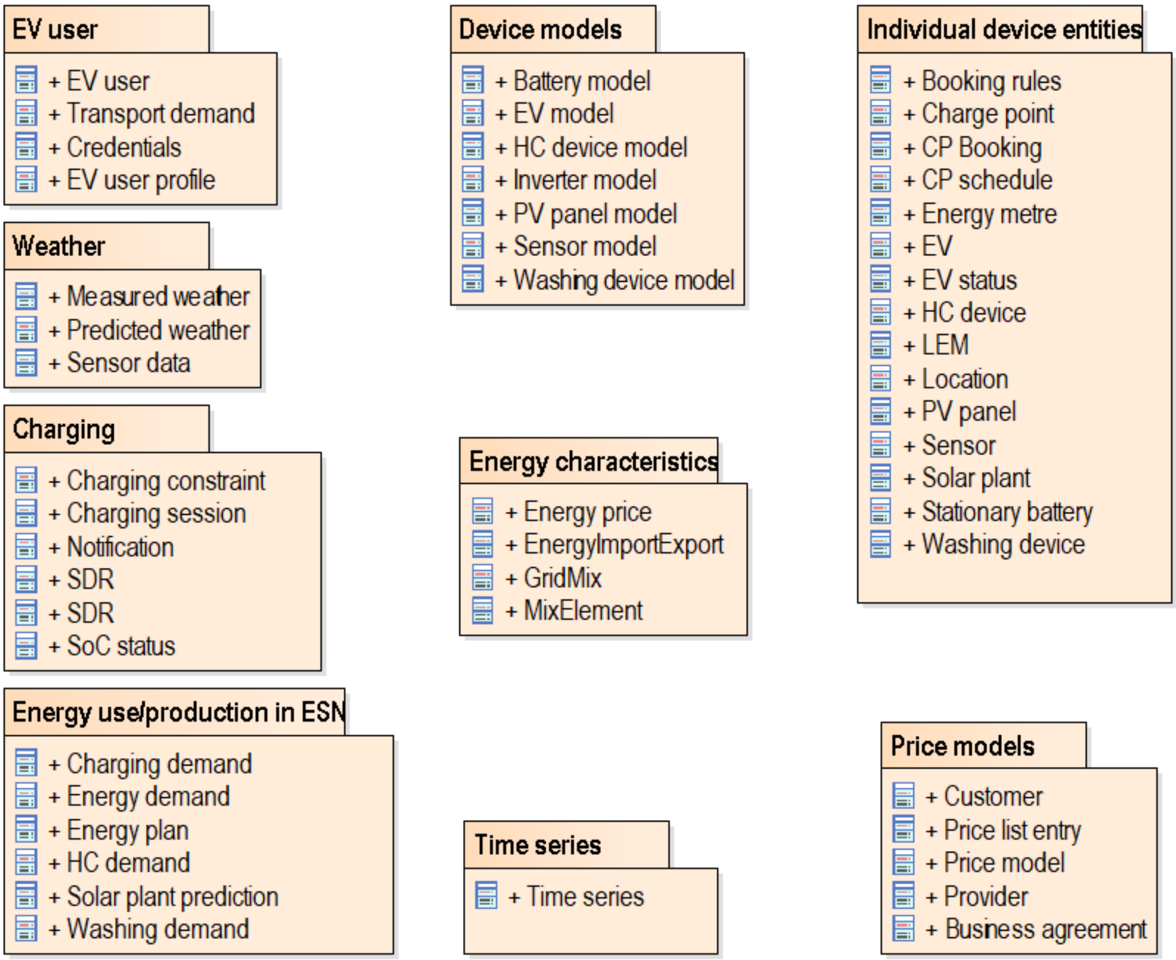

Figure 7-1 Overview of information sub-models with information classes

The sub-models are described in the following sections by means of UML class diagrams, and they are, when appropriate, coordinated with the research data described in deliverable D5.6 Open research data. The notation used is described in B.2.

The information classes in the sub-models are depicted inside a boundary. The the relations between these information classes as well as towards other classes (depicted outside the boundaty) are also specified.

Use of this model as a blueprint in system architecture descriptions: The information model addressed the information that is exchanged between the systems. Based on the need for interaction with other systems, the information elements of relevance should be identified.

Note that internally, the system may use other and different information models.

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7.1.1 Information sub-model: Device models

The device model sub-model is depicted inside the boundary in Figure 23, and the relations to information classes in other sub-models (those outside the boundary) are also shown.

The information classes describe the characteristics of models, e.g., EV models. An EV model will for example be a certain brand and model, e.g., VW eUp with a certain battery capacity. The device model information classes are, as illustrated by the figure, linked to actual individual device entities. The EV model is for example linked to individual device entities representing real EVs, and the corresponding EV model class provides details on the EV model characteristics.

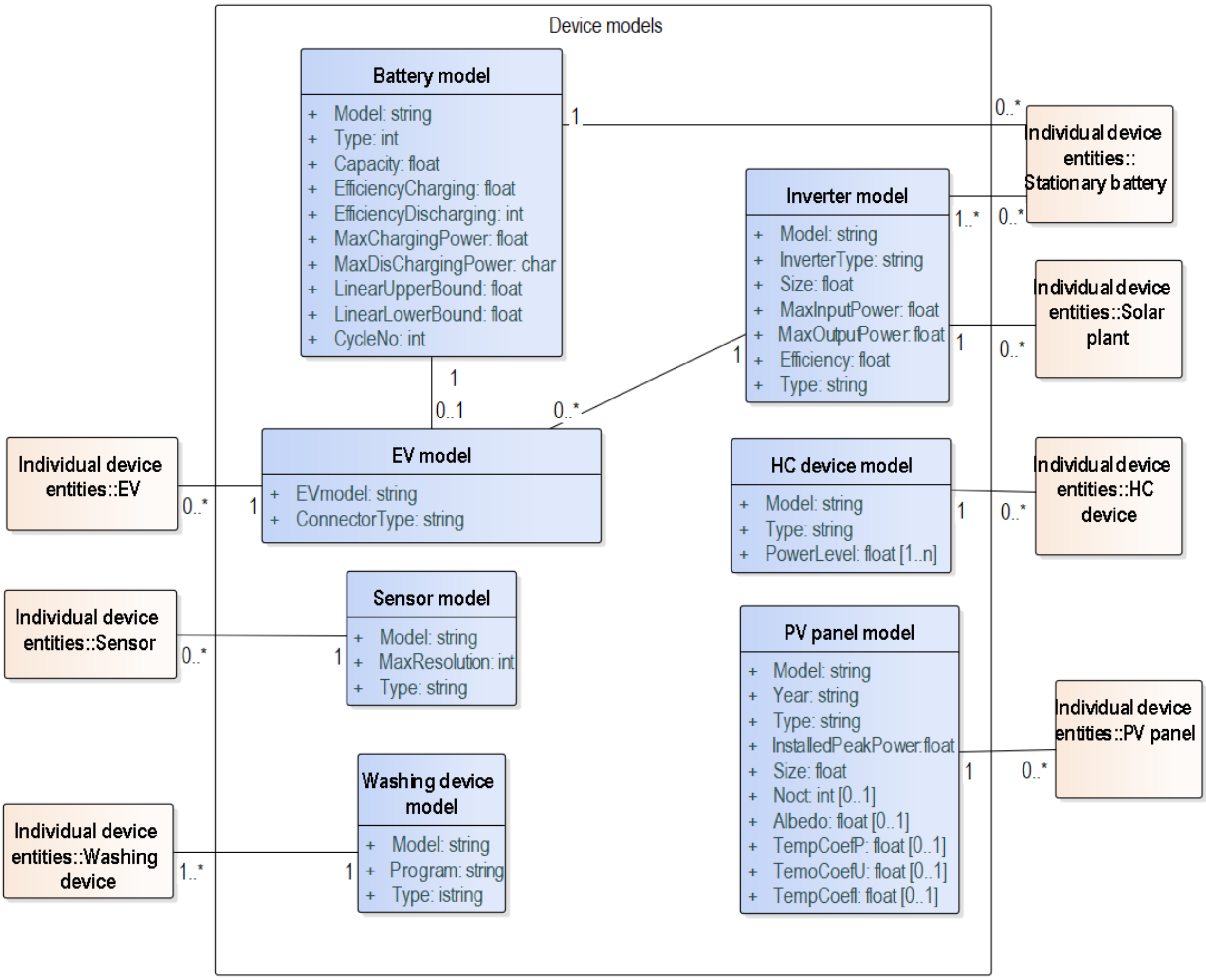

Figure 7-2 Information sub-model: Device models

7.1.2 Information sub-model: Individual device entities

The individual device entities sub-model is depicted inside the boundary in Figure 24, and the relations to information classes in the device models sub-model (outside the boundary) is shown.

Some comments to the model:

- All entities except for the EVs are linked to a Location. The geographical location may be defined by means of coordinates to facilitates the localisation of charge points located along a route.

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 Local Energy Management (LEM) system may be the top of a hierarchy of LEMs.
- A Solar plant is composed of one or more PV panels.
- A Solar plant may have a link to a Stationary battery for storage of surplus energy.
- A Charge point has overall information about its capacity, the possibility of making in advance bookings (attribute advance reservation), V2G support, and operational status. The latter is used to indicate malfunctions.
- If a Charge point can be booked in advance, the following information may be provided as described by the Booking rules. CP schedule and CP Booking classes. The Booking rules class provides overall information on the booking ability: The minimum time resolution that can be booked, the maximum time in advance the booking can be done, the time that must be in between bookings, the maximum duration of the time slot that can be booked, and the minimum time in advance that the booking can be cancelled The CP schedule and CP Booking classes indicate when the charge point is available for new bookings.
- The EV has data on the current status regarding milage, SoC, and driving mode used (e.g., eco driving).

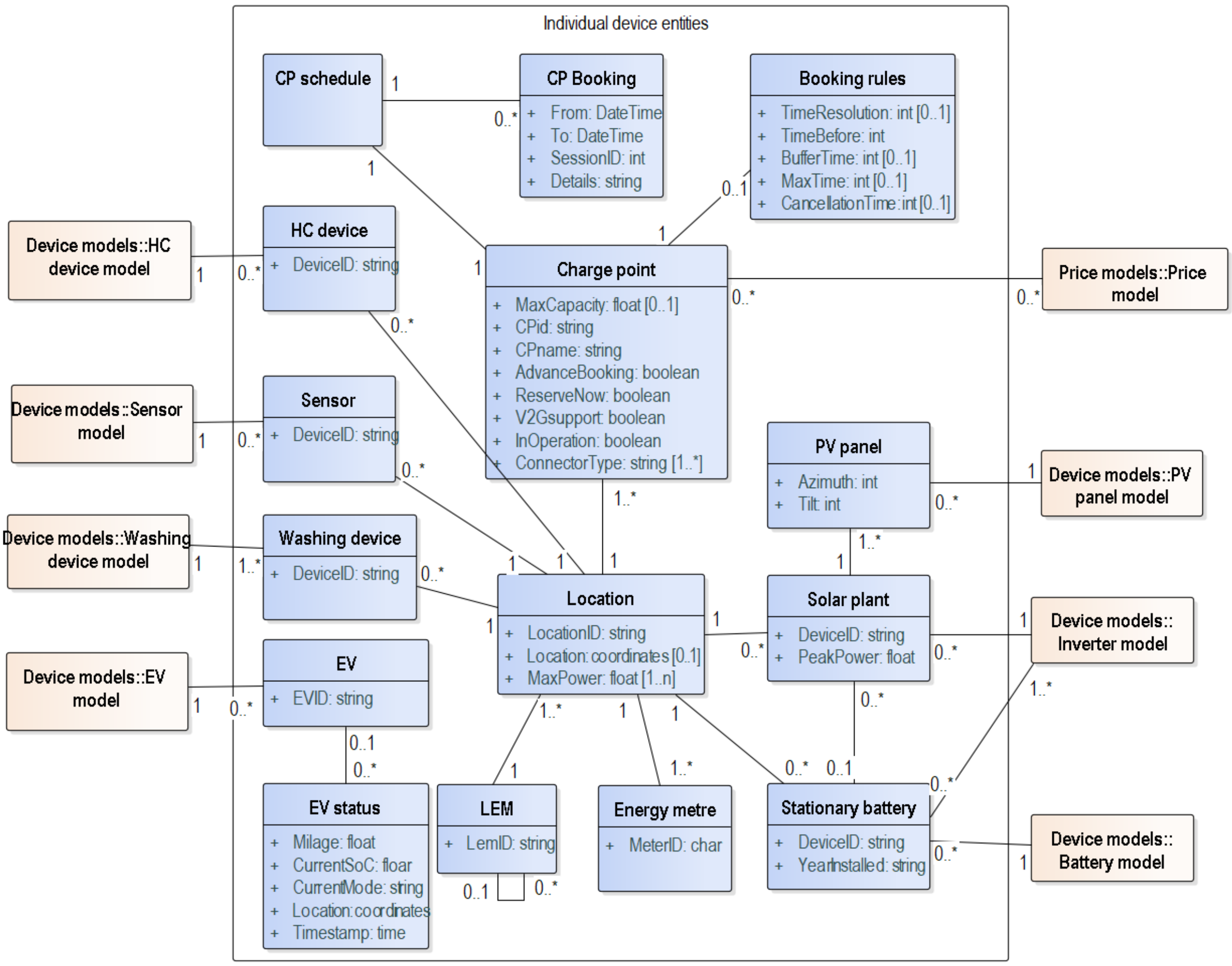

Figure 7-3 Information sub-model: Individual device entities

7.1.3 Information sub-model: EV user

The EV user sub-model is depicted inside the boundary in Figure 25, with a link to the EV class in the individual device entities sub-model (outside the boundary).

The transport demand class define the route and the start and locations. If charging is needed, a charge plan will be established. The plan links to the booked charging sessions.

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The transport demand may not be a complete description of the transport demand (i.e., a planned trip) but is included to show that some information on the trip is needed to support the charge planning.

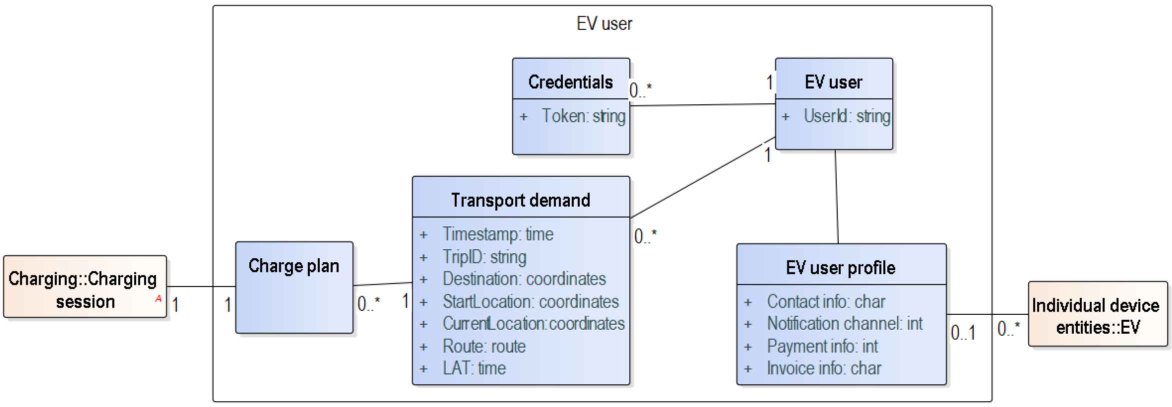

Figure 7-4 Information sub-model: EV user

7.1.4 Information sub-model: Energy characteristics

The Energy characteristics sub-model is depicted inside the boundary in Figure 26, with links information classes in other sub-models (outside the boundary). Some comments to the model:

- The Grid mix is for a certain time period, and there is one Mix element providing the share of energy from each energy source type. The types may be: Biomass, fossil brown coal/Lignite, fossil coal-derived gas, fossil gas, fossil hard coal, fossil oil, fossil oil shale, fossil peat, other fossil, geothermal, hydro pumped storage, hydro, marine, nuclear, other renewable, solar, waste, wind Offshore, and wind Onshore.
- The energy exported and/or imported from/to the grid or to other parts of the ESN is provided as time series.
- The energy price may have two types of components – a varying price component provided as a time series and fixed price components provided by price models and associated Price list entries. Different types of prices may be provided, e.g., price of energy imported to the grid, price of energy exported to the grid (by procumers), and price of energy sold to others within the ESN (by procumers).

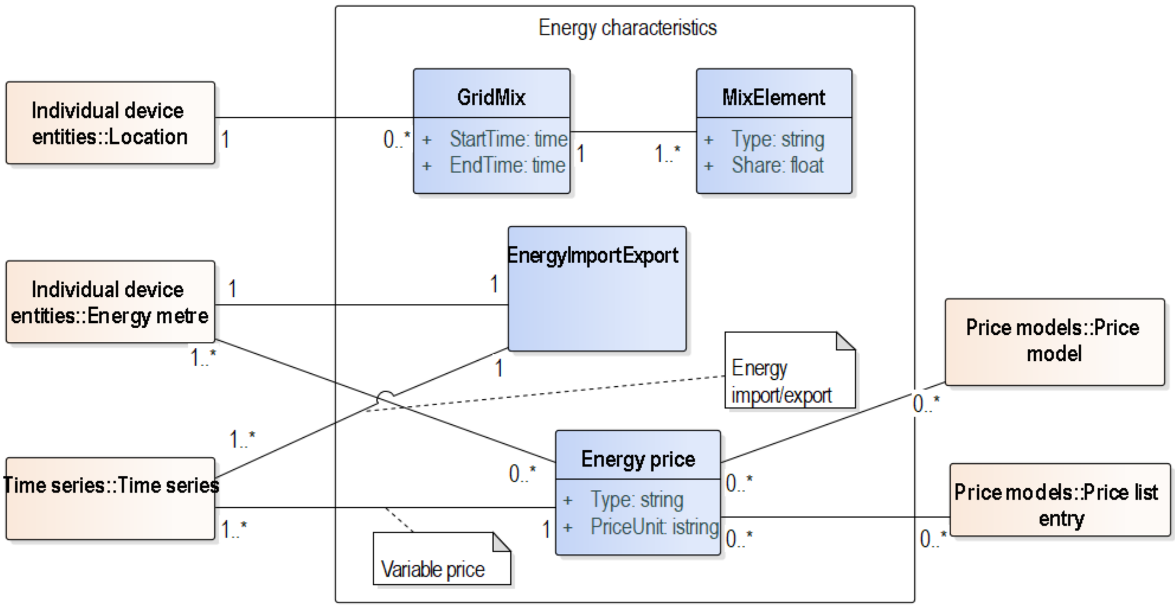

Figure 7-5 Information sub-model: Energy characteristics

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7.1.5 Information sub-model: Charging

The Charging sub-model is depicted inside the boundary in Figure 27 with links to information classes in other sub-models (outside the boundary). Some comments to the model:

- **Charging session** identifies the actual charging/discharging session. It has a charging constraint as well as a selected Price model and Price list entry, a Location, and a Charge point where the charging is requested. It is also linked to the to be charged (and the EV has a set of properties, the connector type included). It also links to the time series describing the charging/discharging.
- The **Charging constraint** is crucial for smart and green charging. It defines the user demand with respect to when the charging should be done, and the energy requested. At the same time, it defines the information needed for the local energy management, to facilitate optimal use of energy. The data elements define
    - **The timeslot in which the charging should be done**. The timeslot is defined by ArrivalTime and DepatureTime.
    - **The energy requested.** This is the difference between target and initial SoC.
    - **The minimum energy content**. MinSoC is the minimum "standby" charge level, in case an unforeseen need to use the car occurs. Smart charging should try to reach this level ASAP, while the rest may be subject to load shifting.
    - **The maximum energy content**. MaxSoC is the SoC that should not be exceeded in case of V2G.
    - **Priority.** If this indicator is true, priority charging is requested.
    - **V2G is allowed**. If this indicator is true, V2G is offered, and energy from the EV's battery can be used by the local energy management system. The EV must however be charged according to the constraints at the LFT.

  SoC status is information about the current SoC provided to the EV User at any time during the charging.
- **Notification** is status updates that are provided to the user at any time.
- **SDR** is the service detailed record describing the charging session that is accomplished.

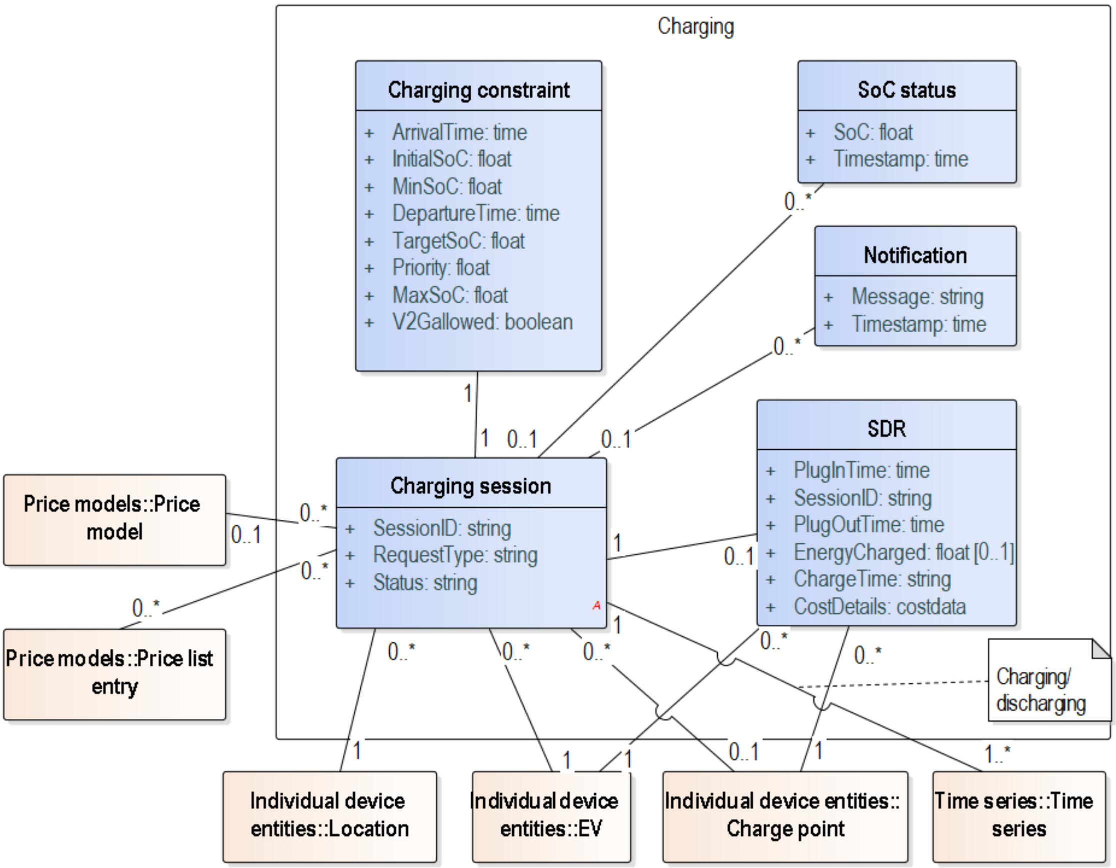

Figure 7-6 Information sub-model: Charging

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7.1.6 Information sub-model: Energy use/production/storage in ESN

The Energy use/production/storage in ESN sub-model is depicted inside the boundary in Figure 28 with links to information classes in other sub-models (outside the boundary). Some comments to the model:

- **Energy demand.** All energy demands have a link to their associated individual device entries:
    - **HC demand** (heating/cooling) has a timeslot, a setpoint, and an allowed deviation from the setpoint that defines when heating/cooling should be activated. The flexibility is a corridor defined by two time series.
    - **Washing demand** has a time slot and a program, and a time series defining the profile of the program.
    - **Charging demand is** defined by its charging constraint, the battery model, and the charge point.
- **Solar plant prediction.** The energy use will be planned based on predictions of the production of from each solar plant.
- **Energy plan.** When the energy use is optimised, each individual entity gets a plan with a time series defining the planned energy use.

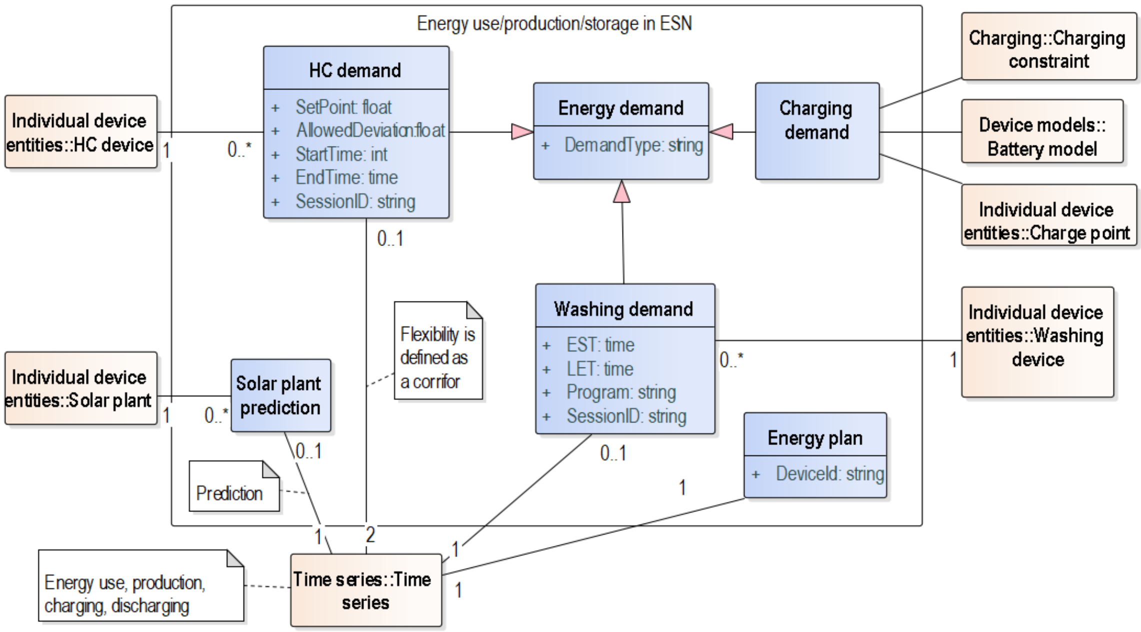

Figure 7-7 Information sub-model: Energy use/production/storage in ESN

7.1.7 Information sub-model: Price models

The Price model sub-model is depicted inside the boundary in Figure 29 with links to information classes in other sub-models (outside the boundary). Some comments to the model:

- A Price model may have several Price List entries. The latter represent the price of a specific service, service level, or product.
- The Price models and the associated Price list entries represent static price components
- A Price model address type of payment, which indicates what the payment is for. This may for example be payment for: Charging, EV rental, undesired behaviour (a penalty), desired behaviour (discount – as a reward), transfer of energy, electricity, charge management, roaming, use of energy, a service, use of locally produced energy within ESN, etc.
- The Price model payer and receiver roles indicate the roles of the stakeholders involved. The roles may be EV user, EMP, CPO, Property inhabitant/owner, Public Grid Actor, Energy consumer/prosumer, Fleet operator, and Roaming operator. Note that an employer can be represented by Property inhabitant/owner.

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- The Price list entry describe details on the actual prices used during a period (defined by start time and end time). A price type may indicate that a price is a fixed price, a price per time unit, as price per kWh, a price per highest kWh, or a percentage added to the total. The Time unit is provided in case of time per time unit. The currency and price value provide the price.
- The Price model is linked to a Business agreement between a Provider and a Customer.

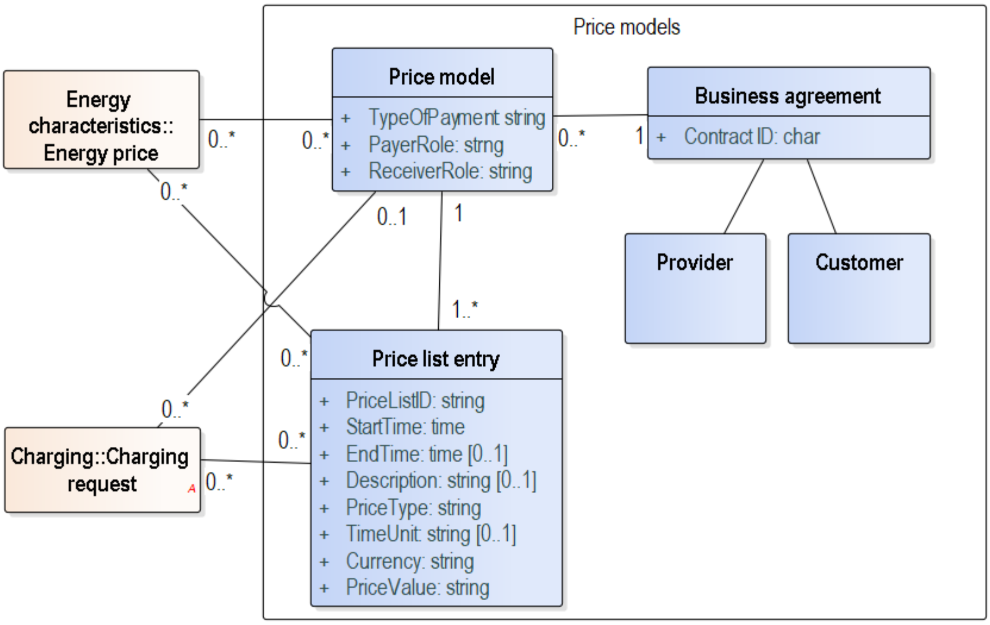

Figure 7-8 Information sub-model: Price models

7.1.8 Information sub-model: Weather

The Weather sub-model is depicted inside the boundary in Figure 30with links to information classes in other sub-models (outside the boundary). The weather is of relevance since it may affect the use of energy in general, the charging of EVs included. Some comments to the model:

- Both the Predicted weather and the Measured weather is provided by means of Time series. The type indicates the type of the values provided. This may be temperature (unit degrees in Celsius), insolation (unit kWh per m2), wind (unit m per s), and precipitation (unit mm per hour).
- Sensor data may also be of relevance, and this data is also provided in Time series.

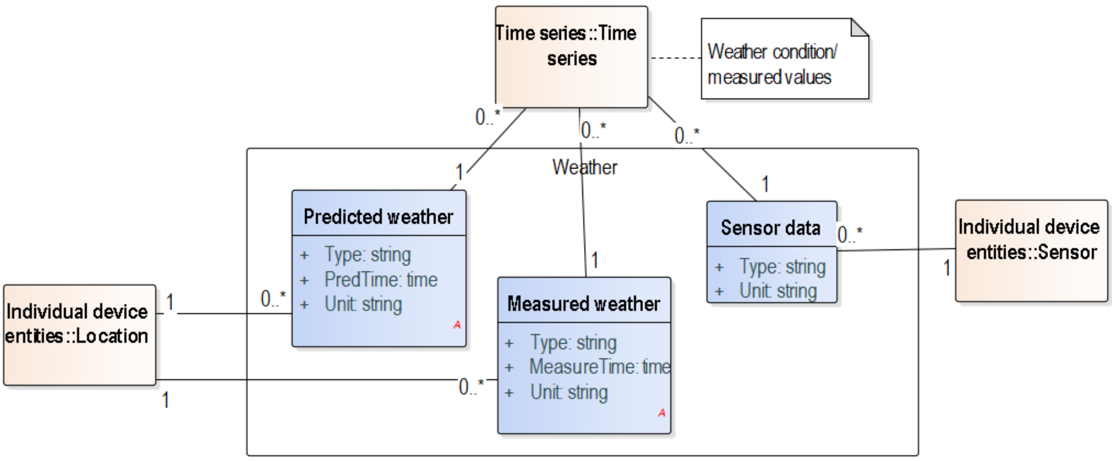

Figure 7-9 Information sub-model: Weather

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

7.1.9 Information sub-model: Time series

The Time series sub-model is depicted inside the boundary in Figure 31 Figure 30with links to information classes in other sub-models (outside the boundary). Some comments to the model:

- The Time series may provide data on energy import (positive increment), energy export (negative increment), energy use (positive increment) and energy production (negative increment)
- The Time series may provide data on weather related issues and sensor data.
- The Time series may provide data on charging and discharging sessions, both related to the charging/discharging of EVs and the charging/discharging of stationary batteries.
- The Time series may provide data on varying prices.

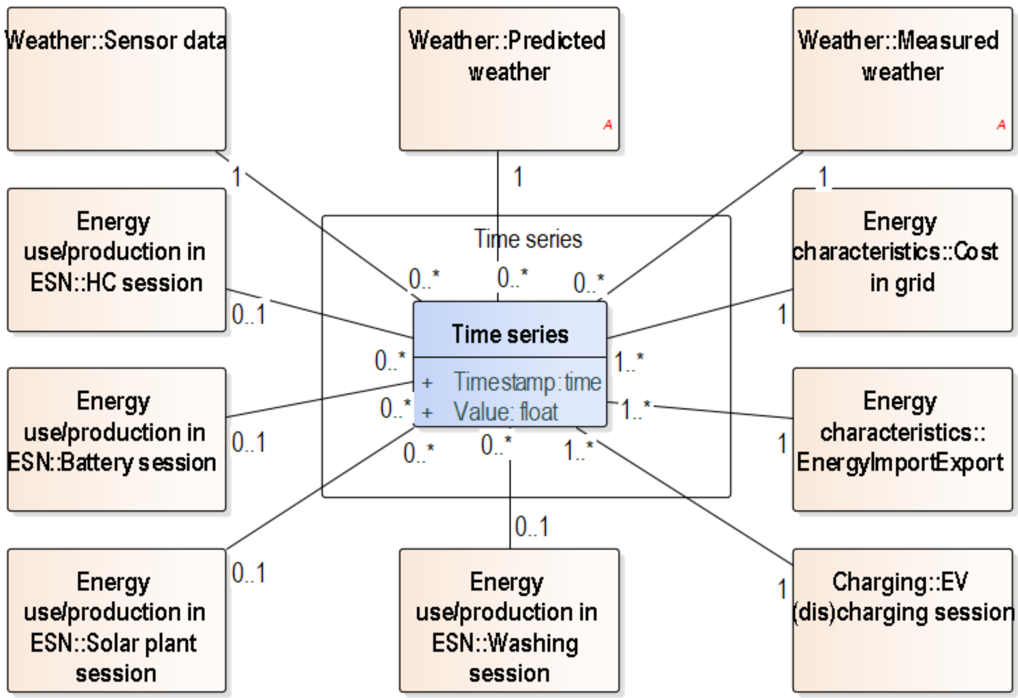

Figure 7-10 Information sub-model: Time series

7.2 Service and interface model

The GreenCharge system is modelled as a set of collaborating services that are meant to be implemented by modifying and extending existing systems. A participating system may implement one or more of the services, and collaboration between services inside the same system need not adhere to the interfaces defined by the architecture. This means that the architecture does not enforce a particular structure on the set of participating systems.

Figure 32 is a UML component model illustrating the high-level logical components (services) of the GreenCharge system, the external components they interact with, and the interfaces through which they collaborate through message exchange. These services and the mapping from use cases to services have been described in section 5.2.

Note that the Fleet management service does not interact with the Charge Point Operation service since the Fleet operator logically is a specialisation of the EV User and will "use" a Charge Service Provisioning service, (possibly implemented by the own fleet management system) when charge services are requested and used.

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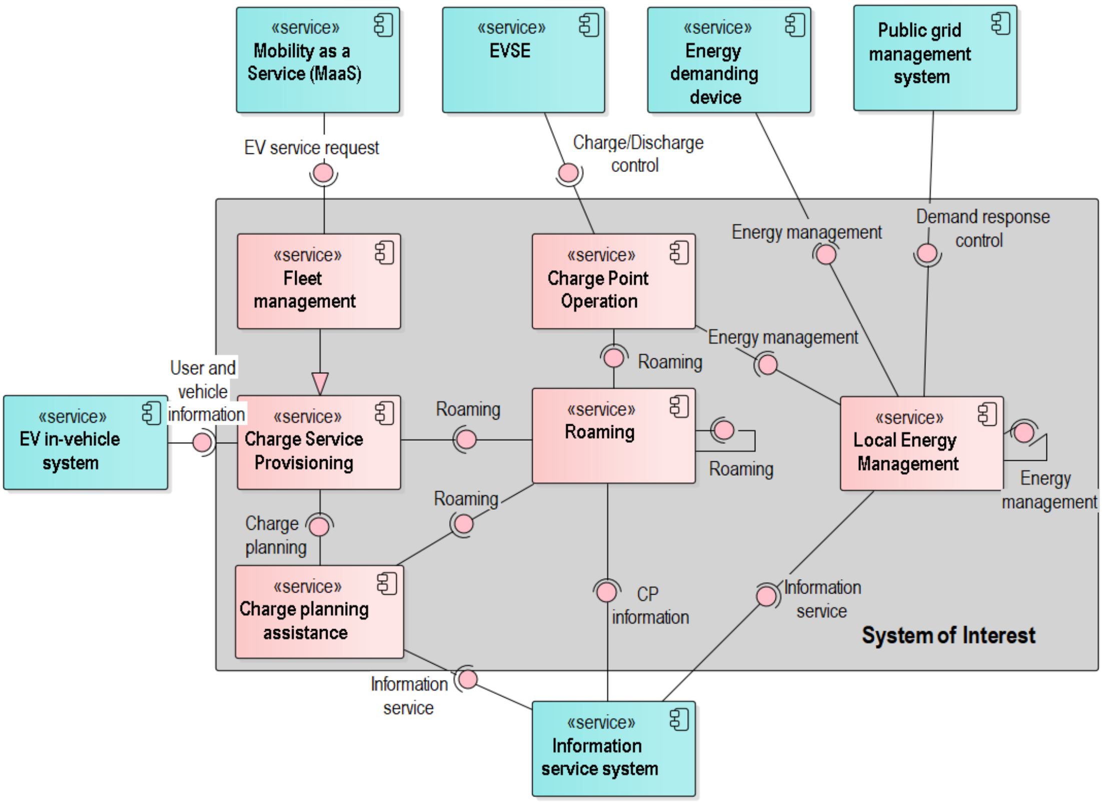

Figure 7-11 High level logical components and interfaces

The interfaces provided by the internal logical components/services are:

- *Roaming.* The interface is provided by the Roaming service, and the interface is further defined in section 7.2.1. Note that all information exchange regarding the charging is exchanges via this interface. It includes novel aspects compared to current standards and support the following information exchange
  - Information exchange between the Charge Service Provisioning service (provided by the EMP) and the Charge Point Operation service (provided by the CPO). According to the requirements provided in 6.6, this interface should preferably be realised according to IEC 63119 and IEC 63119-1 ED1 – Information exchange for Electric Vehicle charging roaming service (when ready) and ISO 15118 Road vehicles - Vehicle to grid communication interface.
  - Information exchange with the Charge planning assistance service. In this case, the interface will support the access to charge point information.
  - Information exchange between Roaming services provided by different Roaming Operators.
- *Charge planning.* This interface supports the interaction between the Charge Service Provisioning service (provided by the EMP) and a service supporting charge planning. The interface is described in 7.2.2.
- *Energy management.* The interface is provided by the Local Energy Management service and facilitates information exchange on energy demands and offerings. Plans for the use of energy are optimised, taking the energy availability (local production and local energy storage included), all energy demands, and the ability for local storage of energy (V2G included) are considered. For charging, the plan may also include the use of V2G. The interface is described in 7.2.3

  Note that component Local Energy Management may exchange messages with other local Energy management components in the hierarchical Local Energy Management solution.

The interfaces provided by the external components are:

- *User and vehicle information.* The interface facilitates access to data on the user and vehicle, among others the EV status (e.g., SoC data, milage, data on the use of eco-mode, etc.) from on-board systems. The interface is further described in 7.2.4.

- *CP information.* This interface supports the sharing of charge point information. This will be static data about charge points (location, speed, connector types, etc.) but may also be real-time data, e.g., data on charge point availability and dynamic prices. The interface is further described in 7.2.5.
- *EV service request.* This interface is decided by the EV Fleet Operator and/or the MaaS operator. The interface is not further described here.
- *Charge/Discharge control.* According to the requirements provided in 6.6, this interface must be realised as defined by the Open Charge Point Protocol (OCPP 2.0) standard and is thus not further described here.
- *Demand response control.* This interface is decided by the Public Grid Actor. The interface is not further described here.
- *Information service.* This interface is decided by the information systems providing the information service and is not further described here. The interface may provide many types of information. For example:
    - The Charge planning assistance service may need meteorological data, data on road topography, POI (point of interest) data, etc. to be able to plan the charging.
    - The Local Energy Management service may need meteorological data and data on energy prices and tariff to predict energy use and to optimise the use of energy.

The messages exchanged through the Vehicle information, CP information, Roaming, Charge planning, and Energy management interfaces are described in the following sections, with references to the message data to be exchanged. The message data refer to classes and attributes in the information model in section 7.1.

Use of this model as a blueprint in system architecture descriptions: The interfaces of relevance should be identified based on the services of relevance (decided through the use of the "Use case to service mapping model" in section 5.2). The associated message data should be used. In the same way as the services are to be understood as abstract components that must be mapped to real systems in an implementation, the messages are to be understood as abstract messages that must be mapped to agreed real protocols.

7.2.1 Roaming interface

The messages and data exchanged are described in Table 3.

All these messages are always sent via one or more Roaming service instances. *In the table below we indicate only the origin and destination service.*

Table 7-1 Messages communicated via Roaming interface

Message	From component	To component	Message data	description (comments)
CS info request	Charge planning assistance	Charge point operation	Route, preferences and constraints;	Request for information about charge stations and their offered CPs along the route
CS info update	Charge point operation	Charge planning assistance	CP information	Response to CS info request and
	Charge point operation	Roaming	CP information	Update of information about the charge station and the associated CPs when changes occur
Availability request	Charge service provisioning	Charge point operation	Charging session, Charging constraints;	To check if the CP is available in the case of drop-in charging
Availability update	Charge point operation	Charge service provisioning	Session id, CP schedule (1..*);	Response to the availability request or

Charging request	Charge Service Provisioning	Charge point operation	Charging session, Charging constraints;	Can create, update the constraints of,or cancel a charging session.
Charging response	Charge point operation	Charge Service Provisioning	Charging session;	Response to a charging request message. The status field of the Charging session indicates if request is approved or rejected, and if rejected the reason.
Start charging	Charge Service Provisioning	Charge point operation	Charging session;	Signals that the EV has arrived
Status request	Charge Service Provisioning	Charge point operation	Charging session,	Request for the status of an ongoing charge session.
Status update	Charge point operation	Charge Service Provisioning	Charging session, SoC, Power, Current, Estimated time to complete;	Response to a statues request message, provides information about the progress and current status of the charging session.
Charging completed	Charge point operation	Charge Service Provisioning	Charging session, Service detail record (SDR)	Return SDR when EV is disconnected
Stop charging	Charge Service Provisioning	Charge point operation	Charging session;	when the EV user wants to end and ongoing charging session from the app before completed

7.2.2 Charge planning interface

The messages and the data exchanged are described in Table 4.

Table 7-2 Messages communicated via the Charge planning interface

Message	From component	To component	Message data	description (comments)
Planning request	Charge service provisioning	Charge planning assistance	Trip id, Transport demand, EV model, EVstatus.	Request charge planning assistance for a planned trip
Planning response	Charge planning assistance	Charge service provisioning	Trip id, Charge plans (1..*)	List of alternative charge plans

7.2.3 Energy management interface

The message data exchanged via the messages are described below through references to the information model in section 7.1. Further details om the messages are provided in Table 5.

Table 7-3 Messages communicated via Energy management interface

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.

Message	From component	To component	Message data (see details in information model	description (comments)
Energy request	Charge point operation	Local Energy mgmt.	Energy demand	The energy demand for a charging session, initial or update.
	Energy demanding device Smart home app	Local Energy mgmt.	Energy demand	The energy demand of an energy demanding device, either sent directly from the device or from an app used by an inhabitant, initial or update
	Local energy management	Local energy management	Energy demand	In a hierarchy of LEMs, aggregate demand of a LEM below sent to the LEM above. May include possibility of periods with net production.
Energy response	Local energy management	Charge point operation	Energy plan [1..*]	Optimal charging profile for one or more CPs. For a V2G enabled CP it may also include periods of discharging.
	Local energy management	Energy demanding device	Energy plan	Optimal consumption profile
	Local energy management	Local energy management	Energy plan	In a hierarchy of LEMs, aggregate consumption profile of a LEM above sent to a LEM below. May include periods with net production from the lower-level LEM.
Energy characteristics report	Local Energy mgmt.	Charge point operation	Energy characteristics	Based on the logs of energy use
Energy use report	Charge point operation Energy demanding devices	Local Energy mgmt.	Energy use	Report on the actual energy use for charging and other energy demanding activities
	Local Energy mgmt..	Local Energy mgmt.		

7.2.4 User and vehicle information

This interface represents the necessary information exchange between the Charge service provisioning service and onboard software systems assisting the user while driving and managing the charging of the EV, e.g., battery management system or navigation system. The interface can be realised in several ways:

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- As defined by the OBD2 standard, according to the requirements provided in 6.6.
- Open APIs provided by the OEMs over the Internet. There are commercial companies offering common APIs across several OEMs, but the solution must be standardised.
- Direct message exchange with assisting systems, or through dialogue with the user on a suitable user interface device (e.g., EV onboard touch screen or a smartphone).

The data exchanged are described below through references to the information model in section 7.1.

- Transport demand in the EV user information sub-model in section 7.1.3
- Charge plan

7.2.5 CP information

The data exchanged via the messages are the same as in the CS info message defined in the Roaming interface.

7.3 System collaboration model

To further illustrate the collaboration between the services, this section presents typical collaboration scenarios in the form of UML sequence diagrams. The diagrams show the message flow and information exchanged through message parameters. In the diagrams the information transferred through a message exchange are indicated in parenthesis following the message name. The information is indicated informally by a few describing words. Further details about the representation of the exchanged information are described in the message descriptions above.

EV user and Building inhabitant/user appear as actors in some diagrams because their interaction with the system triggers most message flows. This interaction may take place through a user interface on a suitable device (e.g., smartphone or EV touch display) with the actor itself, or directly with systems assisting the actor (e.g., EV navigation system, EV battery management system or smart appliances in their home). Information exchange between these actors and the GreenCharge services are indicated using the “virtual” message “Dialogue”.

Use of this model as a blueprint in system architecture descriptions: The sequence diagrams of relevance should be used as a guideline for the interactions to be realised. The actual sequence diagrams for the system to be implemented should be defined.

7.3.1 Plan and follow up trip requiring charging underway

This scenario illustrates the message flow when an EV user plans a trip requiring one or more charging stops underway and wants to book the necessary charge stops to avoid waiting in queue, including message exchange before the first charge stop and between subsequent ones if any, to monitor progress and adapt the charge plan if progress deviates too much from what was expected. It is important that the CPO is notified as early as possible of any changes to the planned arrival time, the charging constraints, or cancellations in order to maximise the utilisation of its CPs.

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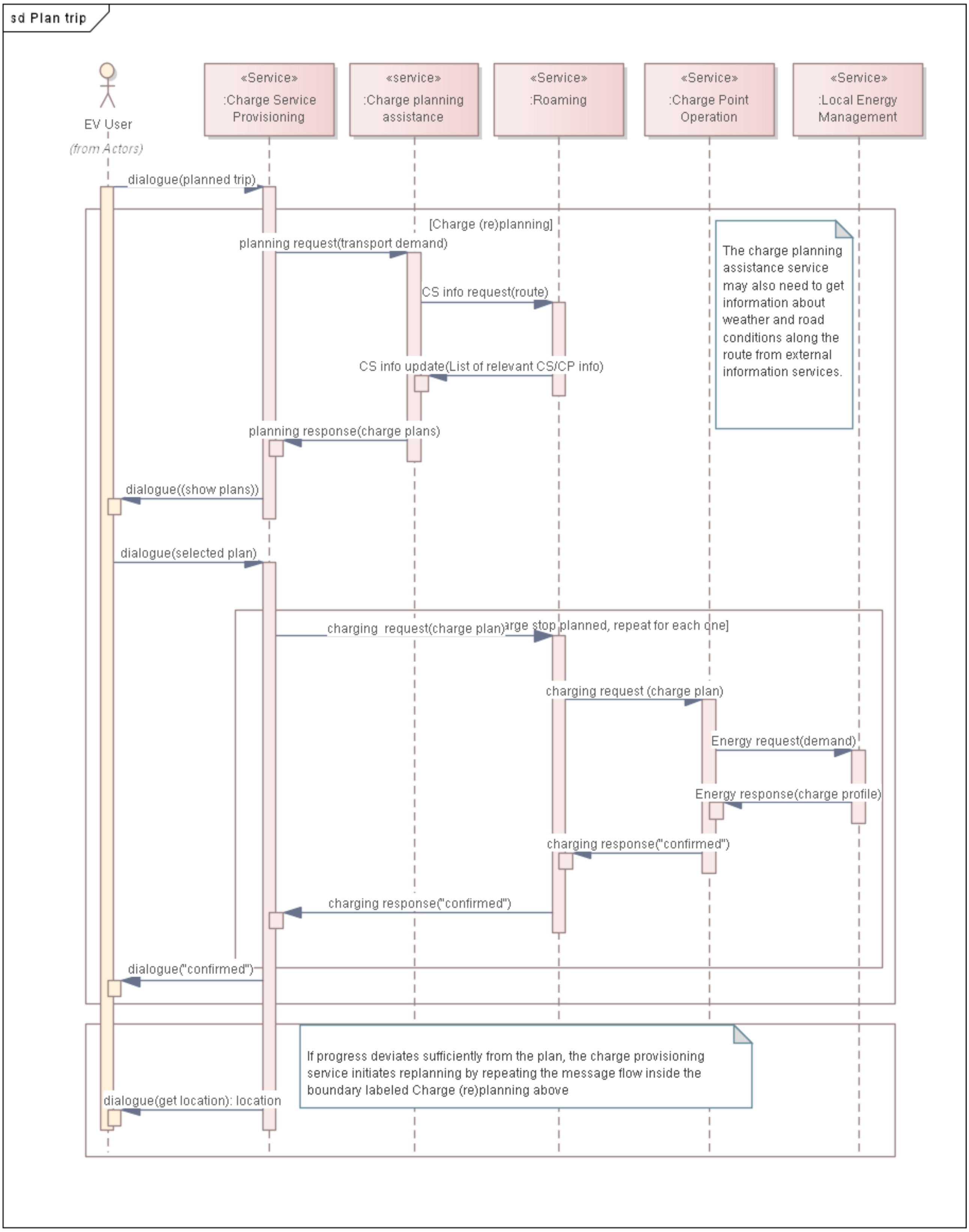

Figure 7-12 Plan trip, book charging, follow up progress and replan and rebook if necessary.

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

7.3.2 Charging at booked charge station

This scenario illustrates the message flow when an EV arrives to a CP booked in advance. There are two alternatives: a) The EV automatically authorises the charging with the Session id of the booking through the charging cable and the CP operation service verifies against the information in the CP schedule, or b) the user authenticates through the Charge service provisioning service using its user interface.

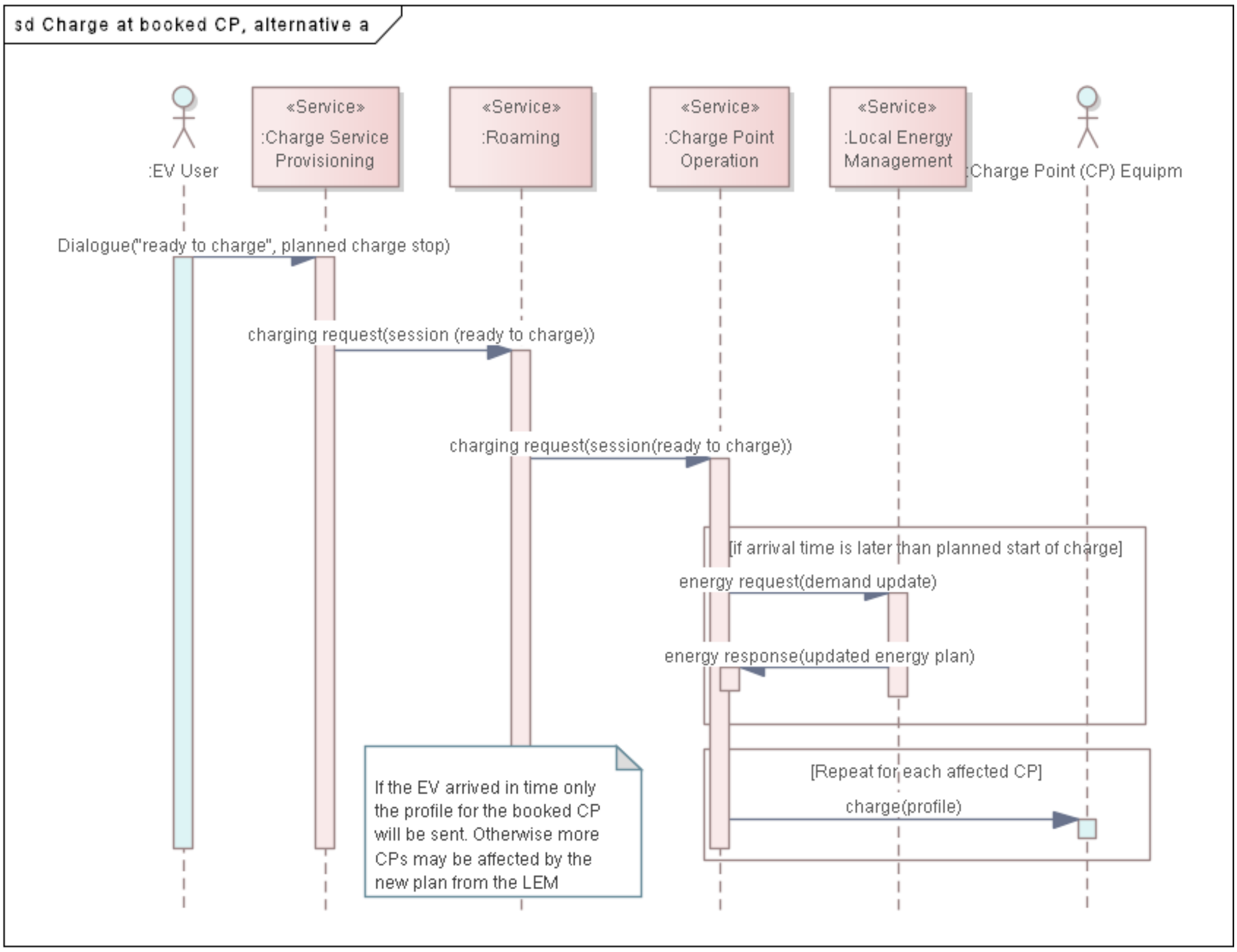

Figure 7-13 Charging at booked CP, alternative a)

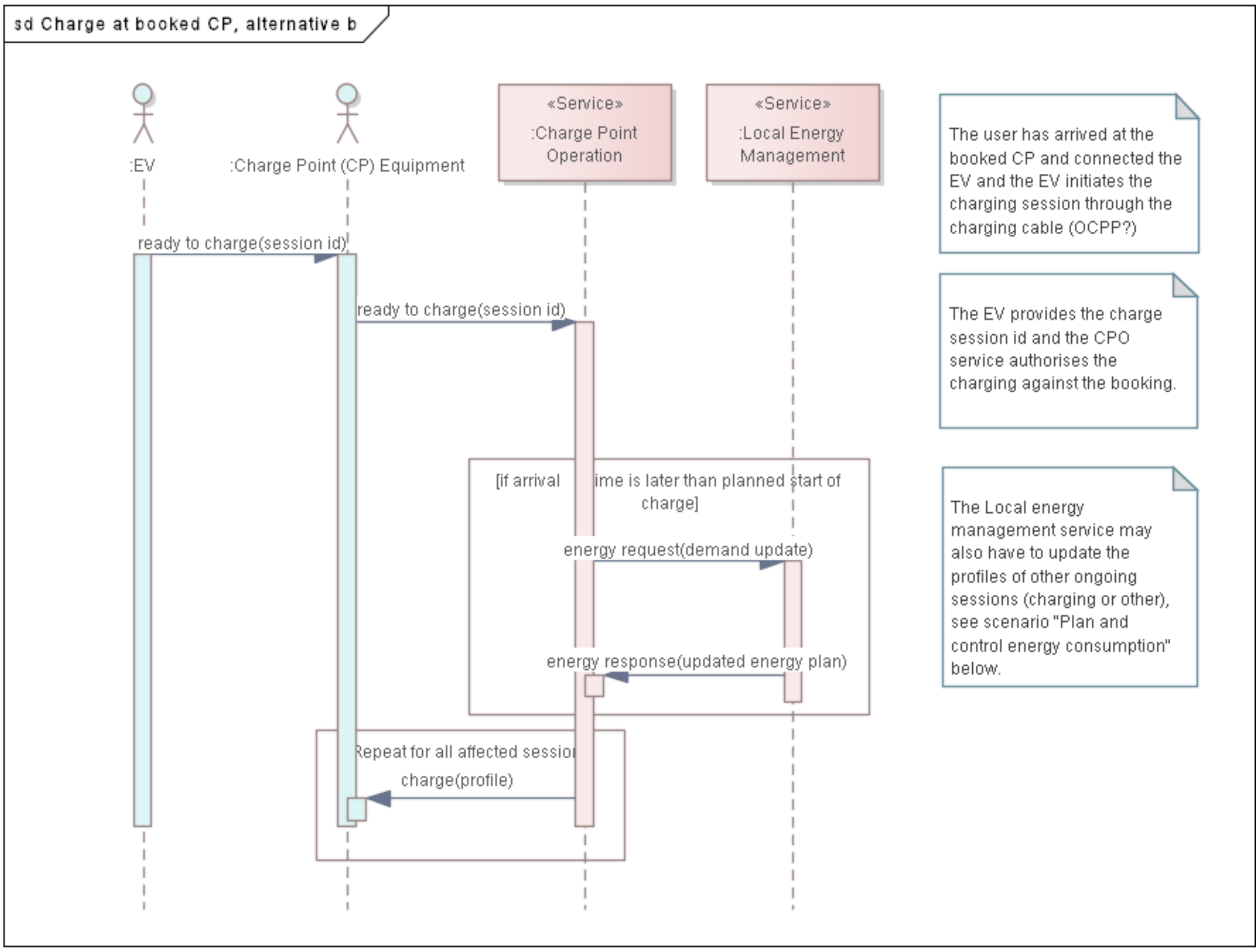

Figure 7-14 Charging at booked CP, alternative b)

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

7.3.3 Drop-in charging

This scenario illustrates the message flow when an EV user arrives at a free CP and connects the EV without booking in advance.

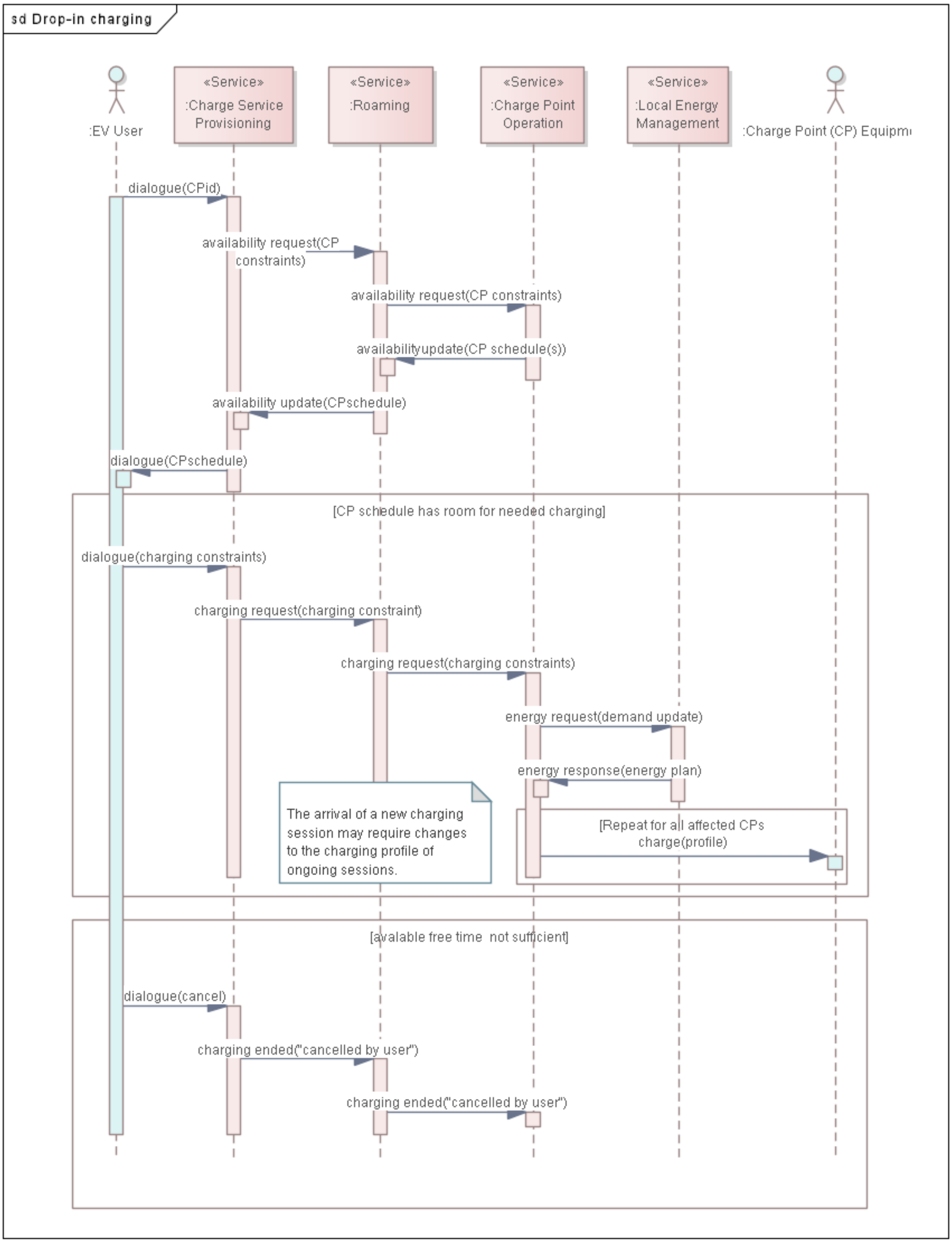

Figure 7-15 Drop-in charging

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

7.3.4 Charging at private chargepoints

A private chargepoint that is not shared and gets power from the owners house, may be treated as other flexible devices in the house and planned and controlled through the user interface to the LEM service. If it is meant to be shared part of the time, i.e. made available to other users in periods when the owner knows he will not use it, it must be operated by a Charge point operation service, and the owner books it in advance for the periods he does not want to share it. The Chargepoint operation service could be one offered by a commercial CPO, or it could be a simplified one implemented in the CP and connected to a roaming hub.

7.3.5 Report charging progress

This scenario illustrates the message flow ensuring that the user is appropriately informed about the progress of the charging session and possible irregularities

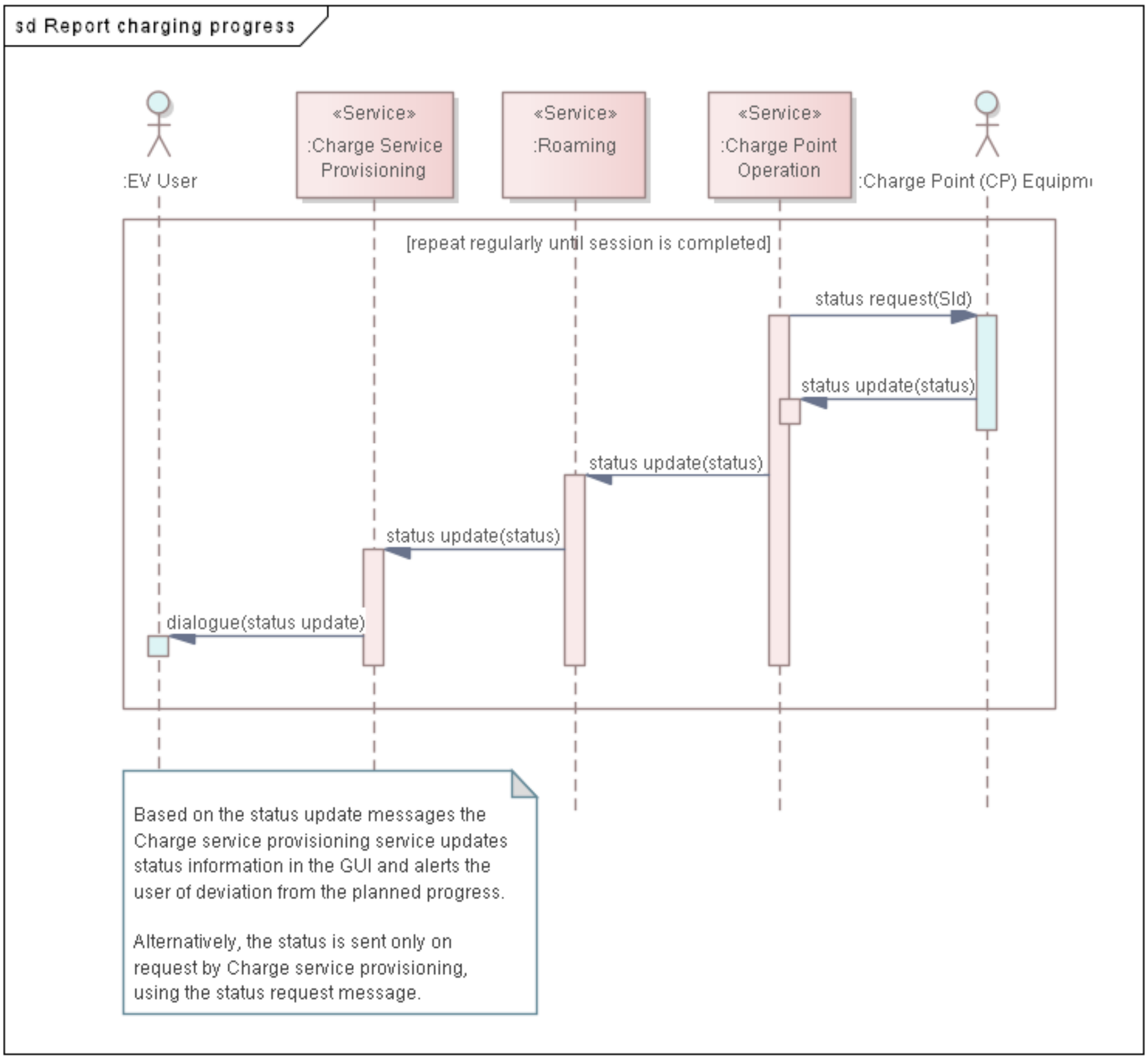

Figure 7-16 Report charging progress

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

7.3.6 Plan and control energy consumption

This scenario illustrates the message flow when a Charge point operation service requests energy for a charge session, or the inhabitants in the ESN plan energy demand in the member buildings through the user interface of the Local energy management service, for example the use of washing machines, driers, dishwashers, fridges, freezers, room heating or cooling devices and DHW devices. It is assumed that the building inhabitants provide constraints and preferences regarding shifting of the energy consumption of these devices to optimise the energy consumption of the neighbourhood.

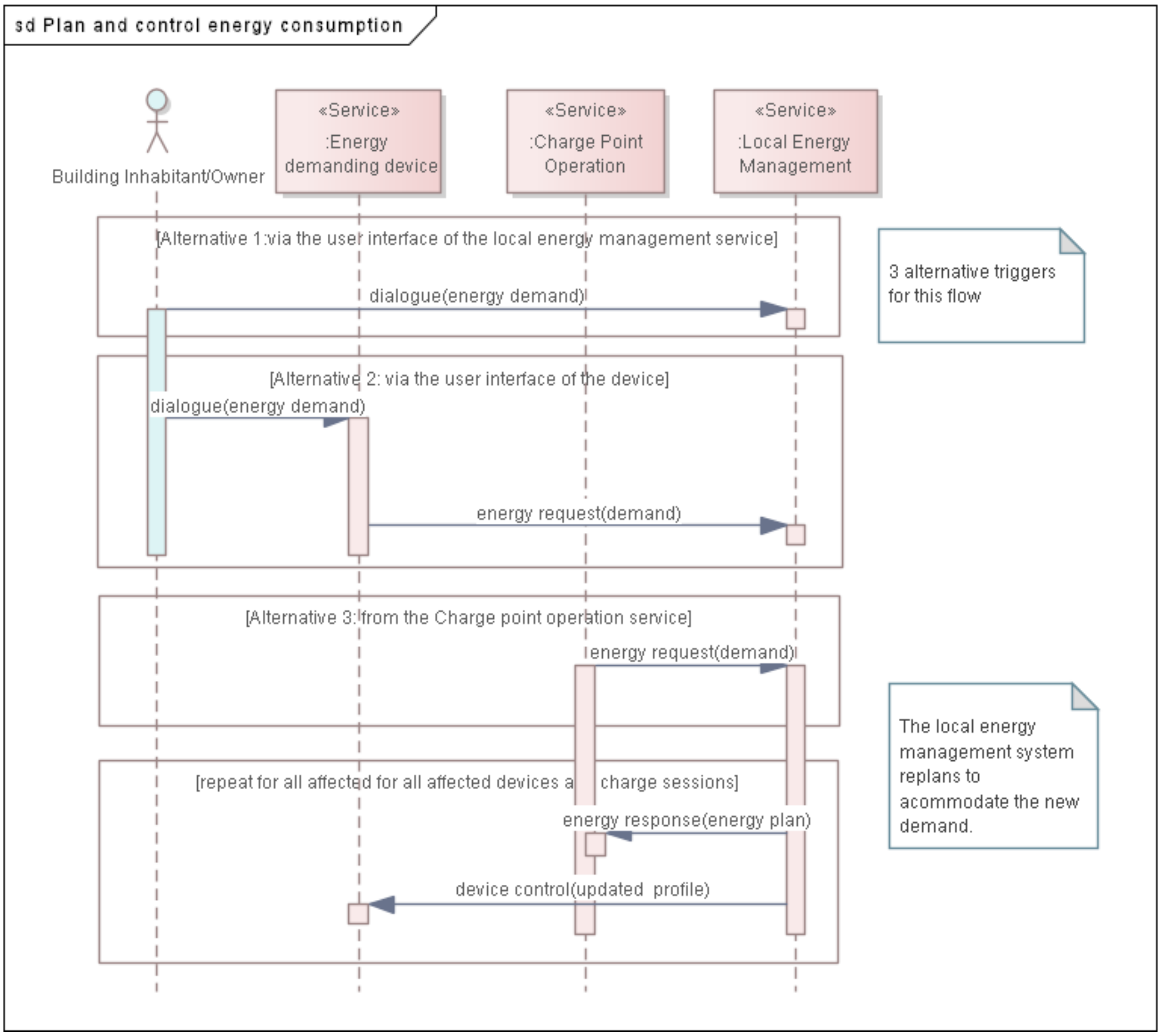

Figure 7-17 Plan and control energy consumption

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

7.3.7 Hierarchic local energy management

In some cases, a neighbourhood contains entities with their own local energy management system, for example large buildings or charge stations. The following diagram shows examples of the dialog between a neighbourhood energy management system, an energy management service of a charge station.

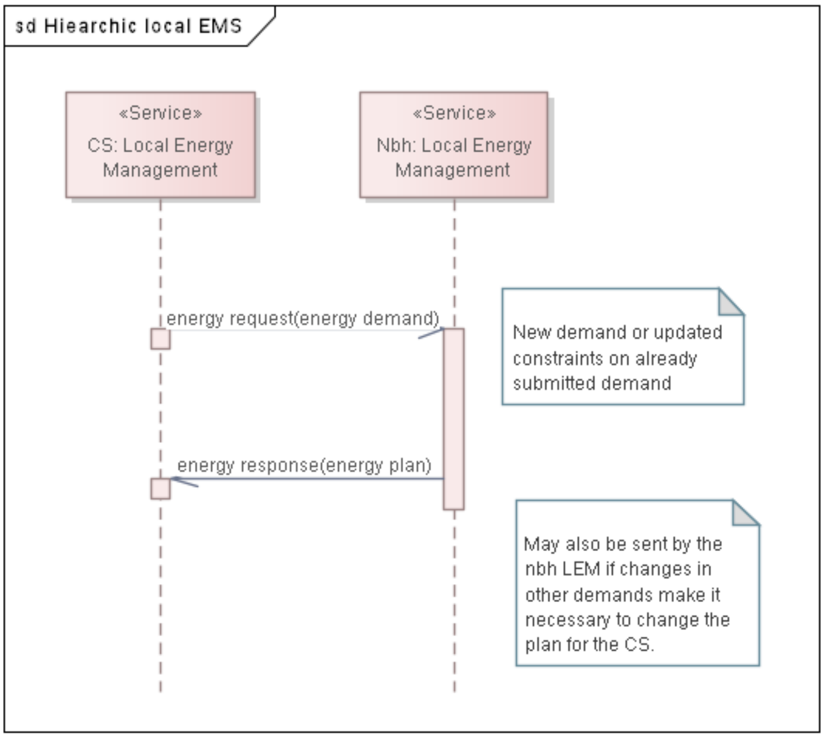

Figure 7-18 Hierarchical local energy management

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

8 Deployment view

A System Deployment Model usually describes how the logical components (use cases, services, etc.) will be realised by real system components and deployed together. This reference architecture description does not define the distribution of software and hardware components into systems, and the realisation of the target systems and their deployment to the environment. These issues must be decided by the system owners. However, this section illustrates how a concrete system of systems for smart and green charging can be realised with regard to the reference architecture specifications using three examples from the GreenCharge pilots. The examples selected comply with the GreenCharge concept, and they illustrate different approaches such a realisation through integrations of existing systems as well as new developments.

As the main goal of the GreenCharge Reference Architecture described in this deliverable is to facilitate the integration of existing systems into a desired system of systems, the descriptions in this chapter focus on the mapping between logical services defined in the Reference Architecture and the available technologies, the system collaborations (the interactions between software system components with regard to the services they provide), and the adaptions needed.

Use of these examples in system architecture descriptions for inspiration: the examples in this section illustrate how existing systems can be integrated to realise selected functionalities for smart and green charging according to the local context through adaption/extension of existing system and needed new development.

We recommend that the system owners focus on the following aspects when planning for the realisation of the integration work:

- Selected subset of use cases to be supported – to define the desired functionality of the target system
- Technology Mapping Model – to describe how system components map to technological solutions, concepts, and mechanisms. A key task is to map the services provided by existing systems to the logical services defined in Section 5.2.
- Changes to be done - identify the needed adaption of existing system and the new development
- System collaboration - which components are interacting with each other
- Interfaces to be implemented (from the Service and interface model in section 7.2).
- System Integration Test Model - to describe the test scenarios to be conducted during system deployment.

8.1 Smart energy management with smart charging in the garage (OSL.D1)

The GreenCharge Oslo Demo 1 (OSL.D1) addresses the smart charging and energy management of the garage of a housing cooperative. Around 60 charge points (CP) are installed over 4 floors in the garage. In addition, roof-installed solar panels and a stationary battery on the ground floor are installed to facilitate charging with green energy. A prototype of system of systems (SoS) realising four services defined in the Reference Architecture is deployed in the garage as illustrated in Figure 37. This prototype manages the CPs in the garage and offers users with *flexible charging* (default option, which offers flexibility for load balancing and shifting) and *priority charging* (which has priority when there is not enough energy to fulfil all demand). The prototype also supports *optimal and coordinated use of energy*.

The *Fortum Charge & Drive management* implements *Charge point operation* service for the control of the CPs. The *ZET App & Charge Management backend* implements *Charge Planning Assistance* and *Charge Service Provisioning* services. The EV user can use the ZET App to enter charging requests (select flexible charging or priority charging and define charging constraints), initiate charging, manage user account and provide user profile information (such as information about the EV and default values for charging to simplify the charging requests). Moreover, the EV user can monitor the charging process and the estimated SoC via the App. The *eSmart Connected Prosumer platform* and the *ZET individual charge planning* together provide the *Local Service Management* service. The eSmart Connected Prosumer monitors issues that may affect the

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energy use and availability (weather, RES production, charging demands with varying flexibility, stationary battery, heating cables, etc), and calculates a dynamic *overall capacity plan* for optimal energy use. This capacity plan gives predicted total capacity per zone[2] in the garage that can be used for the next 48 hours with 15 minutes interval. The *ZET Individual Charge Planning* then generates *individual charge plan* for each CP when it receives the capacity plan. Based on the individual charge plan, the Fortum system controls the start and stop of the charging as well as the energy transferred at individual CPs. In addition, the eSmart system also sends control plans to the battery management system for the charging and discharging of the stationary battery.

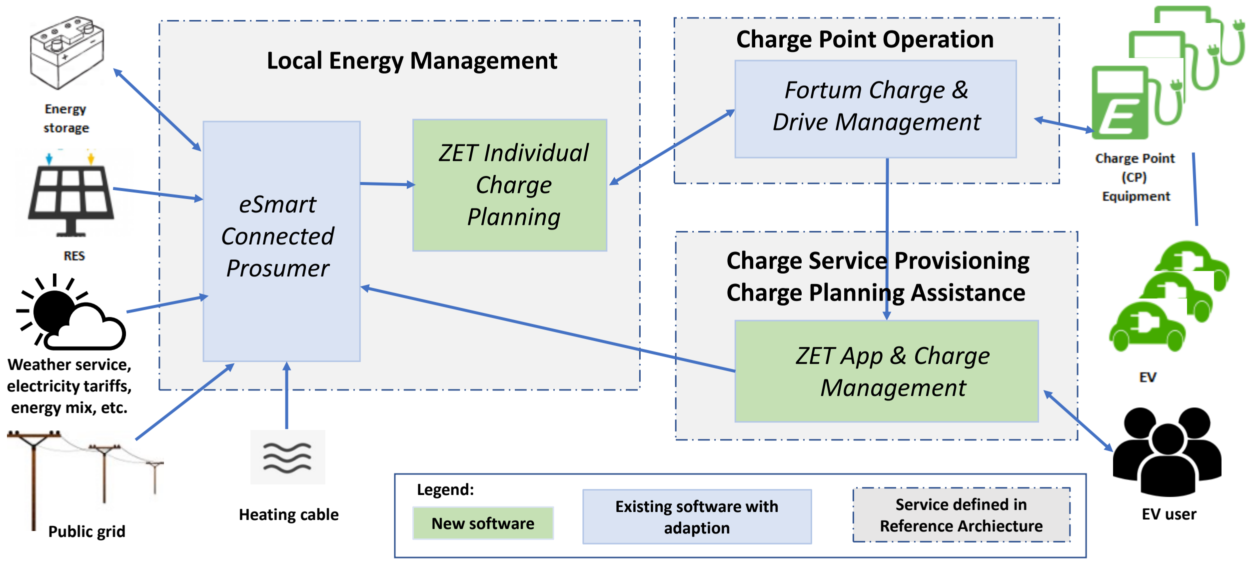

Figure 8-1 System components and interactions for the OSL.D1 prototype (Jiang, Natvig et al. 2022)

The eSmart Connected Prosumer system and the Fortum Charge & Drive management system are commercial systems. To reduce the changes of the operational systems, special design has been done for the integrations and leads to the design and implementation of the new development of the ZET components as described above. Some lessons learnt for this implementation and special design:

- As there is no standard interface to obtain SoC automatically, the App is used to collect such information from the user manually. The accuracy of the user provided input affects the quality of the optimisation in the overall capacity plan.
- Ideally, LEM should send individual charge plans to CPO as described in the Reference Architecture. But in OSL.D1 case, the ZET Individual Charge Planning component was introduced to generate individual plans based on the overall capacity plan to reduce the changes of the existing eSmart Connected prosumer and Fortum Charge & Drive Management system.

8.2 Sharing of CPs with booking and roaming (OSL.D2)

The GreenCharge Oslo Demo 2 (OSL.D2) demonstrates sharing of private CPs through booking and roaming. Visitors or people working in the neighbouring buildings can book and use the four outdoor chargers owned by the housing cooperative through the Roaming Operator (Hubject) without the need of an existing subscription with the CPO (Fortum).

The prototypes realising four services defined in the Reference Architecture is deployed for OSL.D2 as illustrated in Figure 38. The *ZET App & Charge Management backend* implements *Charge Planning Assistance* and *Charge Service Provisioning* services. The user can use the ZET App to find an available charge

[2] The garage has been divided into several planning zones with limits on the total charging power.

point, enter charging requests with constraints, initiate charging and manage payment information (such as credit card). It is basically the same App as used in OSL.D1. OSL.D2 implement advance booking of CPs by means of the *ZET Charge Booking Calendar* (together with ZET App realising the *Charge Planning Assistance* service). The *Hubject eRoaming Management System* provides *Roaming* services and connects the CPO system (Fortum Charge & Drive Management) and the EMP system (ZET App & Charge Management). The difference with OSL.D1 is that CPO and EMP systems are now connected via Hubject Roaming platform instead of direct communication. The OICP protocol for roaming has also been extended to get information related to the charging, e.g., about the exact session time and energy charged.

Fortum Charge & Drive Management System and Hubject eRoaming management System are commercial systems. To reduce the changes of the operational systems, special design has been done for the integrations and leads to the new development of the ZET components. According to the Reference Architecture, ideally the booking shall be supported through the roaming protocol so that EMP can get overview of a calendar-based CP availability from CPO. As the current commercial roaming protocol (OICP protocol 2.2) only supports "reserve now" feature, and do not support advance booking, the advance booking is prototyped in the ZET Booking Calendar component. In this sense, ZET components has implemented both EMP and part of the CPO functionality. An extension for eRoaming protocol with standardised interface for advance booking with energy demand will ease the integration and interaction between EMP and CPO with a clearer role

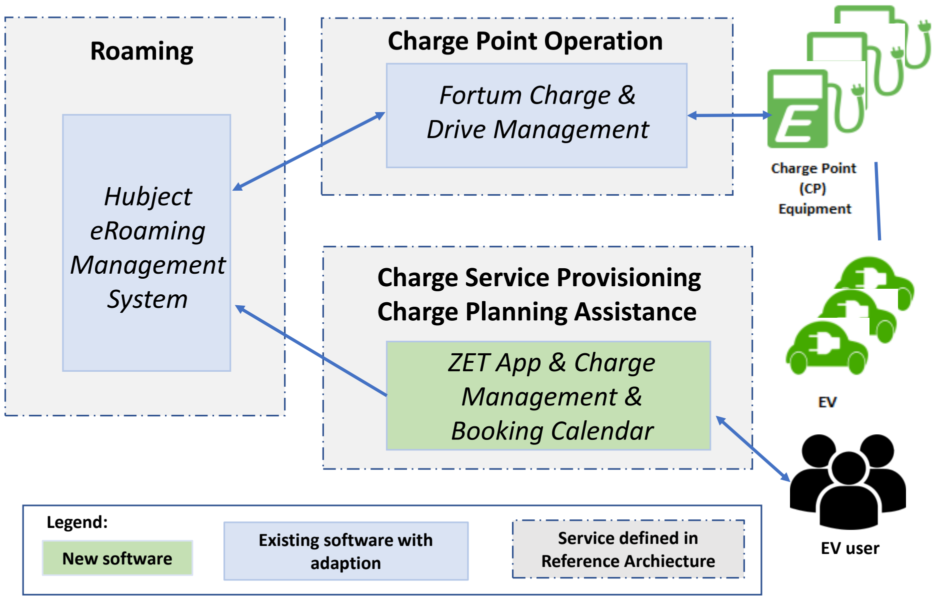

Figure 8-2 System components and interactions for the OSL.D2 prototype

8.3 Smart energy management and charging at work (BCN.D2)

The Barcelona Demo 2 (BCN.D2) demonstrates smart energy management of the office buildings, smart charging with booking and eRoaming. The demo involves two premises of Eurecat with locally installed PV panels, CPs shared with employees and visitors, and a building management system that manages loads of the premises. The booking service allows the employees and visitors to book the CPs at the premises. The smart energy management provides optimal charging taking into consideration of the locally produced solar energy and the rest of the loads of the premises.

The prototypes realising five services defined in the Reference Architecture is deployed for BCN.D2 as illustrated in Figure 3. The *Eurecat App & Booking System* implements *Charge Planning Assistance* and *Charge Service Provisioning* services. The user can use the App to manage CP booking, including defining charging requests with constraints, initiate charging and receive notifications. The Booking System implements an EMP backend. The *Hubject eRoaming Management System* provides *Roaming* services and connects the CPO system (*Eurecat Charge Point Management* which realises the *Charge point operation* service) and the EMP systems (the Eurecat App & Booking System and the ZET App & Charge Management from OSL.D2), so that it can be demonstrated that an EV user with ZET App can charge at the Eurecat premises.

The *Eurecat SEM Scheduler* implements the *Local Energy Management* service and manages the optimisation of energy demand taken into account the charging demands, the rest of the loads of the building, locally produced solar energy, energy tariffs and energy mix.

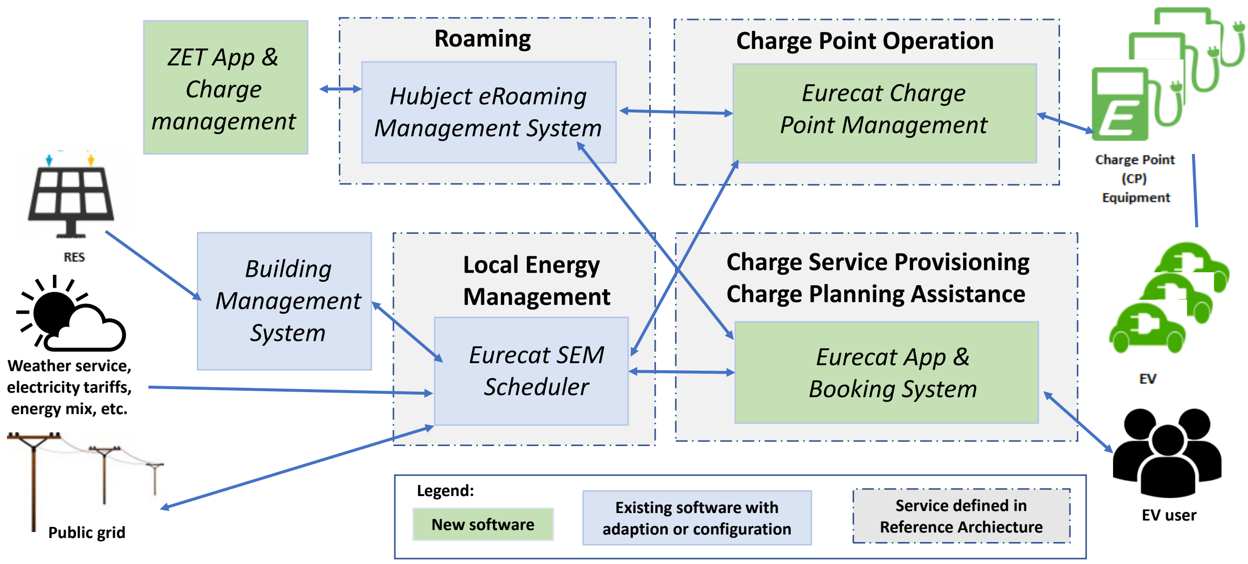

Figure 1 System components and interactions for the BCN.D2 prototype

In this demo, the EMP and CPO functionality has been implemented by the new Eurecat components which are more in line with the Reference Architecture. However, the advance booking via roaming is implemented by the direct interaction between ZET App and the Eurecat Charge Point Management, as the current Hubject OICP protocol does not support advance booking.

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.

9 Recommendations regarding standardisation

The chapter provides input on standardisation needs related to the solutions addressed by this architecture description. The standardisation needs address issues that are crucial for the realisation of the GreenCharge concept:

- The integration of charging in the energy management in energy smart neighbourhoods (ESMs)
- Data collection from electric vehicles (EVs) and EV fleets
- Advance booking of charge points.

9.1 Integration of charging in local energy management

Motivation for new standardisation:

In the future, electric energy will replace fossil energy in many parts of the society, and the demand for electric energy will increase considerably. To avoid problems, the use of energy must be dynamically adapted to the availability.

Today, the energy management in the charge management systems of CPOs is limited. Typically connected EVs are charged at max power (limited by the onboard charger or the CP, whoever is most constraining) The energy available for charging is distributed equally to all connected vehicles. The energy needed by the EV user and the time when a vehicle must be ready for use are not considered. There are no standards for the integration of charging into the local energy management for a building or a neighbourhood. Thus, the charging cannot easily be coordinated with other energy demands.

The charging of electric vehicles is by nature flexible since the vehicles often are connected for longer periods than are needed for charging. In addition, V2G may enable even more flexibility since batteries in connected cars are energy storages that can be charged and discharged several times as long as the vehicles are charged according to the EV users' demand at the end. This is beneficial in several ways. The batteries can be charged when the total energy demand is low and in case of surplus energy from PV panels. Energy from the EV batteries can be used in case of demand peaks.

Due to the lack of standards, there is no easy way to integrate charge management (V2G included) and local energy management. Solutions for smart and green charging must be customized one by one. This is challenging, costly, and not possible under normal conditions.

How it should work:

The charge management must be integrated with the local energy management, and the charging of individual vehicles must be adapted to an overall plan for the use of available energy in the neighbourhood (one or more units/buildings with many energy demanding activities). The plan must take all relevant aspects into account such as current and predicted energy availability, current and foreseen energy demands, current and predicted local energy production, and issues that may affect the energy demand and production (e.g., weather and weather forecasts).

To arrange for the above, the charging request must provide detailed information on the charging demand and the flexibility. This is information on the timeslot when the vehicle will be connected, the amount of energy requested, and the minimum energy demand (in case of energy shortage). The charging request must also indicate whether V2G is allowed or not. Such charging requests may also be provided via roaming services.

The local energy management system will use this the charging request as input to a plan for optimal energy use. The plan will include individual charging (and discharging) schedules for electric vehicles, and the charge management will operate according to this plan.

What is missing in current protocols:

- The ability to book charge points in advance and to specify the flexibility provided (see details in 9.3).
- The roaming of the above (see details in 9.3).
- The integration between charge management and energy management that arrange for optimal energy use in charging.

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Functionality needed:

This architecture document provides specifications that are input to further work on standards regarding the functionality needed. See details in the Use case model in section 5.1:

- Use cases related to the charge planning and booking are provided in 9.3.
- *"Manage energy use and storage"* use case in section 5.1.5 (the planning of optimal energy use)

Protocol requirements:

This architecture document provides specifications that are input to further work on standards for the integration of charge management and local energy management.

Data structures of relevance are defined in the information model in section 7.1. This is mainly t*he Charging demand class in the Energy use/production/storage in ESN sub-model* in section 7.1.6. This class links to the following classes:

- *Charging constraint class in the Charging information sub-model* in section 7.1.5. It does among others define the flexibility and flags whether V2G is allowed.
- *Battery model class in the Device models sub-model* in section 7.1.1. It defines the characteristics of the EV battery to be charged.
- *Charge point class in the Individual device entries sub-models* in section 7.1.2. It defines the characteristics of the charge point to be used.

The interfaces involved are described in the system component and interface model (see section 7.2):

- *Charge planning interface* (see section 7.2.4): This interface supports advance bookings that defines the charging demand.
- *Roaming interface* (see section 7.2.3): This interface facilitates a roaming of advance bookings.
- *Energy management interface* (see section 7.2.4): This interface supports the integration of the charge management into the energy management.

The collaborations involved are described in the system collaboration models (see section 7.3):

9.2 Data collection from EVs and EV fleets

Motivation for new standardisation:

Data from the electric vehicles (EVs) are needed in a standardised way for several reasons. In GreenCharge the following are identified:

- Data is needed in charge planning: Data on the actual state of charge (SoC) is required for the planning of and integration of the charging in local smart energy management. Today, third parties (e.g., providers of charge planning support) cannot access such through standardised interfaces.
- Data is needed for economic incentives: For shared EV fleets, data on the driving mode may be the basis for economic incitements. Use of eco mode may for example be rewarded. Today, such data is available through special agreements with EV providers via proprietary interfaces. The use of standardised interfaces would simplify the access and use of such data.
- Data is needed in fleet management: This is for example data on SoC and milage. Today, such data is available for fleet operators through special agreements with EV providers, via proprietary interfaces. The use of standardised interfaces would simplify the access and use of such data.

How it should work:

A charging request should contain information about the initial SoC (actual SoC when the changing starts) and the target SoC (requested SoC after charging). If the request is sent in advanced, the initial SoC may be estimated based on the current SoC and the planned route to the charge point. When a charging request is sent or updated just before the charging starts, the current SoC should be provided. Thus, the charge planning system must request and receive the current SoC from the EV via a standardised interface.

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Fleet management systems must have access to data from all EVs in the fleet via the same standardised interface.

In any case, it must be possible for a system to access EV data via a standardised interface provided that the system is authorised to get the data.

What is missing in current protocols:
Current protocols do not support access to EV data via standardised interfaces for systems provided by third parties.

Functionality needed:
This architecture document provides specifications that are input to further work on standards regarding the functionality needed. See details in the Use case model in section 5.1:

- Use cases related to the charging request are provided in 9.3.
- *"Manage EV fleet"* use case in section 5.1.3

Protocol requirements:
This architecture document provides specifications that are input to further work on standards for the integration of charge management and local energy management.

Data structures of relevance are defined in the system information model in section 7.1. This is mainly the *EV* class in the Individual device entities information sub-model in section 7.1.2. The following data is provided:

- Milage
- Current SoC
- Mode (e.g., eco driving)

The interface involved is the *User and vehicle information interface* addressed in section 7.2.4. A standardised and open API is needed, and the OEMs should provide the required information via this API. One existing commercial solution is provided by SmartCar and quite many EV brands are supported via the same API. A similar solution should be standardised. As an alternative to exchanging the information directly with the vehicle systems, it may to some extent be exchanged through the user interface of the Charge service provisioning system. In this case the use will have to serve a mediator between the user interfaces of the systems.

9.3 Advance booking of charging

Motivation for new standardisation:
People with no access to private charge points and people driving long distances must use public charge point or other charge points that are shared with others. Due to this and when the EV density increases, charge anxiety may replace range anxiety – they may not get access to a charge point when charging is needed. EV drivers may have to spend time searching for an available charge point, and the waiting time for access to a charge point may be unpredictable and long.

A pre-booking of charging will facilitate more predictable access to charging. Current standards and protocols support "reserve now" – a reservation a short time before the charging. A "reserve now" will immediately block the access to the charge point for all but the EV user that has made the reservation. Thus, the utilisation of charge points may be affected. Charge points may be unused for a time before the right users arrives.

An "advance booking of charging" that can be done a long time before the actual arrival to the charge point is needed. Such bookings should in general not block the use of charge point outside the time slots that are booked.

To facilitate more optimal use of energy, an "in advance booking of charging" should also include information about the amount of energy requested as well as V2G offerings. With the expected electrification of the society, the energy use must be adapted to the energy availability. With advance information on future energy demands

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and V2G possibilities, local energy management systems can better plan, schedule and control the energy use, charging included, in an optimal way adapted to both energy demands and energy availability.

How it should work:

The ability to book a charge point a longer time in advance will improve the predictability, and the utilisation of the charge point will not be affected if others may use the charge point up till the booked timeslot. This is comparable with the booking rules applied for hotels. Cancellation rules and price models must create incitements for the desired behaviour. It must be expensive to not cancel bookings in time it the charge point cannot be used, and the EV user must also pay if the charge point is blocked when it is booked by others (e.g., if the vehicle is not moved away from the charge point when the booked timeslot has expired).

People may manually plan the charging and book the charging according to their needs. However, in the future it is also likely that systems will support and to a large extent automate the charge planning and charge point bookings. Navigation systems may for example do this based on information about the planned route, charge points along the route, the battery status of the EV, the current location of the EV, and temperatures, driving conditions, predicted traffic situations, and topography along the route. The system may issue charging requests with bookings, cancellations of booking, and booking updates depending on how the journey evolves. The charging request may for example have to be updated in case of unforeseen traffic congestions.

Charging requests with advance bookings must also be supported by roaming.

What is missing in current protocols:

- The ability to book charge point in advance without blocking it in the period between booking and planned arrival and to specify the flexibility provided (see details in 9.3).
- The roaming of the above (see details in 9.3).

Functionality needed:

This architecture document provides specifications that are input to further work on standards regarding the functionality needed. See details in the Use case model in section 5.1:

- *"Charge EV"* use case in section 5.1.2 (the provision of charging request booking a charge point for a certain time).
- *"Manage charging"* use case in section 5.1.4 (the booking enforcement)

Protocol requirements:

This architecture document provides specifications that are input to further work on standards for "in advance charging booking".

The data structures of relevance are defined in the system information model in section 7.1.

The charge point information of relevance is defined in the *Charge point class in the Individual device entities information sub-model* in section 7.1.2. The attributes of this class describe the characteristics of the charge point. In addition, it links to the following classes of relevance:

- *Location class in the Individual device entities information sub-model* in section 7.1.2. It defines geographical location of the charge point.
- *Booking rules class in the Individual device entities information sub-model* in section 7.1.2. It defines the overall rules on how bookings and cancellations of bookings can be done.
- *CP schedule and CP booking classes in the Individual device entities information sub-model* in section 7.1.2. These classes define the booked time slots, and thus indirectly also the availability of the charge point.
- *Price model class in the Price models sub-model* in section 7.1.7. It defines the price model offered.

This main data structure for the booking request is the *Charging session class in the Charging sub-model* in section 7.1.5. This class does, among others, link to the following classes:

- *Charging constraint class in the Charging information sub-model* in section 7.1.5. It does among others define the time slot for the booking. Note that this class also supports the smart energy

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management addressed in section for that standardisation of the integration with the local energy management.
- *EV class in the Individual device entries sub-models* in section 7.1.2 and via this class also the *EV model in the Device model* sub-class in section 7.1.1. These classes identify the EV and define its characteristics, among other the connector type needed.
- *Charge point class in the Individual device entries sub-models* in section 7.1.2. It identifies the charge points assigned.

The interfaces involved are described in the system component and interface model (see section 7.2):

- *CP information interface* (see section 7.2.5): This interface is used to exchange information about charge points, among others information about available timeslots that can be booked. This information is needed in the charge planning, and the information must be updated when a timeslot is booked.
- *Charge planning interface* (see section 7.2.4): This interface supports the actual in advance booking.
- *Roaming interface* (see section 7.2.3): This interface facilitates a roaming of the in advance booking.

The collaborations involved are described in the system collaboration models (see section 7.3):

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10 Conclusion

10.1 Supporting the GreenCharge idea

The reference architecture description provided in this document is *a common basis for developing implementations of systems of systems that realize the GreenCharge concept*. The GreenCharge DOA defines seven scenarios linked to the concept. Table 6 lists these scenarios and shows how they are met by the overall use cases described in section 5.1. All scenarios are supported. The use cases identify stakeholder concerns, and the system design provided by this reference architecture description supports a holistic and relevant solutions for smart and green charging.

Table 10-1 How the Green Charge Scenarios are met by the overall use cases in section 5.1

Scenarios from the GreenCharge DOA	Overall use cases in reference architecture						
	Manage charging account	**Charge EV**	**Manage EV fleet**	**Manage charging**	**Manage energy use and storage**	**Enable roaming**	**Plan and execute other energy demanding activities**
Charge planning and booking	X	X		X	X	X	
Charging at booked charge station	X	X		X			
Booking Enforcement	X	X		X			
Home charging in … buildings with common internal grid and parking facilities, or at work in buildings with similar limitations				X	X		X
V2G	X	X	X	X	X	X	
Reacting to Demand Response (DR) request					X		
E-Mobility in innovative 'mobility as a service' (MaaS)		X	X				

10.2 Main innovations

Many of the solutions specified by this reference architecture are innovations linked to the cross sectorial collaboration involving the energy, transport/eMobility and building sectors. The innovations suggested are:

Public sharing of extended charge point (CP) information. In addition to information on charge point characteristics (location, type, connectors, etc.) and prices, information on available time slots are provided to support advance bookings of charge points.

Advance booking of charge points. Charge points can be booked several hours or days in advance. The ability to make such bookings provides predictable access to charging. Other EV users may use the charge points outside the booked time slots. The booking is supported by enforcement that ensures the availability of a booked charge point when the EV arrives. Drop in EV User will not be allowed to charge during time slots that are booked by others. Drop-in charging may however be allowed up till the booked time slot.

Charging requests with details on energy demand and flexibility. The charging requests include information on the amount of energy requested, the time slot in which the charging should take place (i.e., the flexibility), and whether V2G will be allowed. Flexibility and V2G arrange for smart energy management.

The idea of smart charge planning support. A navigation system or other system (e.g., an App) may act on behalf of the EV user, and automatically or semi-automatically define the charging request. Default values and historical data may be used to suggest preferences, and the arrival time to the charge point and the slot time

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needed for the charging may be calculated by the system depending on the selected route, the topography of the route, the weather conditions, the foreseen state of charge, and the foreseen energy demand. The system may also do re-calculations and update the charging request in case of deviations.

Charge planning as an integrated part of EV fleet management. The charging of electric vehicle fleets is planned and managed for optimal utilisation of fleet resources.

V2G support. Electric vehicle batteries are offered as an energy storage to the local energy management.

Integration of charge management in local energy management. The local energy management will consider charging demands (received in advance or close to the charging), other energy demands, and the energy availability to plan and manage optimal energy use. The energy availability will include energy imported from the grid, energy from local renewable energy sources (RES), energy from V2G, and energy from stationary energy storages. Optimal energy use will facilitate smart and green charging and arrange for charging with minimal grid investments through peak shaving. V2G can contribute to a paradigm shift from traditional supply control to demand control. Energy surplus can be stored in local energy storages and in the batteries of connected vehicles and used when needed.

The use of tailored price models as a measure to promote desired charging behaviour. The provision of flexibility may for example be rewarded, and undesired behaviour such as blocking of charge points outside the booked timeslot or failing to provide requested flexibility information may be penalised.

10.3 Further use of the architecture

The transition to eMobility is not just about replacing of fossil vehicles with electric vehicles and building charging infrastructures. The energy availability must also be ensured. The electrification of the transport sector will increase the demand for electric energy to a level that may cause problems in local electricity infrastructures and in public distribution grids. New, smart, and green solutions are required, and an integration of the building, energy and transport sectors are needed.

The GreenCharge reference architecture description documents knowledge gained during the GreenCharge project, and this knowledge supports further work towards a full electrification of the transport domain.

New technical solutions. The architecture description can, as described in section 2.1, be used as a blueprint when the systems needed for smart and green charging are designed and integrated.

Standards for integration of systems. The integration of charging in Energy Smart Neighbourhoods (ESNs) is challenging due to the lack of standardised interfaces. Today, each interface must be customised to the individual systems involved. Chapter 9 describes the standardisation needs and refers to the parts of the architecture description that are input to the required standardisation work. When standards are in place, systems from different providers can be integrated, and the establishment ESNs will become feasible.

Technical solutions accompanied by new business models. The aim of the new business models must be twofold: Economic sustainability and behavioural changes. The first is the traditional focus in business models. The latter is more novel. Economic incentives can be used to encourage EV users to provide the flexibility needed and to book charge points and energy in advance. The reference architecture addresses the use of technology in combination with business models, but this must be further explored in real business cases.

Technology and business models supporting the Energy Smart Neighbourhood (ESN) concept. The architecture description specifies parts of the technology needed. In addition, new technology must facilitate the realisation of the business models constituting ESN value networks. Several parts of the architecture description, e.g., the information models in section 7.1, can support the development of such technology.

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References

Aldea, A., M.-E. Iacob, J. van Hillegersberg, D. Quartel, L. Bodenstaff and H. Franken (2015). Modelling strategy with ArchiMate. Proceedings of the 30th Annual ACM Symposium on Applied Computing, ACM.

CIRED Working Group on Smart Grids (2013). Smart Grids on the Distribution Level – Hype or Vision? CIRED’s point of view. http://cired.net/files/download/65.

Enrich, R., A. Rodríguez, B. López, R. Soler, L. Freixas, V. Porta and A. León (2019). "GreenCharge Project Deliverable: D2.16 Description of Barcelona Pilot and User Needs."

Esposito, A., R. Aversa, S. Venticinque, D. Branco, B. Di Martino, S. Hallsteinsen, R. E. Sard and G. Horn (2021). GreenCharge Project Deliverable: D5.3 Simulation and Visualisation Tools (revised version).

European Commission (2011). WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011) 144.

Ferwerda, R., M. Bayings, M. Van der Kam and R. Bekkers (2018). "Advancing E-Roaming in Europe: Towards a Single “Language” for the European Charging Infrastructure." World Electric Vehicle Journal **9**(4): 50.

Günther, B., A. Dittrich, M. Spiekermann, H. Koch, B. Lange and M. Funke (2019). "GreenCharge Project Deliverable: D2.9 Description of Bremen Pilot and User Needs."

IEC (2019). "IEC 63119-1 Information exchange for electric vehicle charging roaming service – Part 1: General."

IEC (2019). IEC 63119-1 Pre-release version (FDIS) Information exchange for electric vehicle charging roaming service - Part 1: General.

IEEE (2000). IEEE 1471-2000 Recommended Practice for Architectural Description of Software-Intencive Systems.

ISO/IEC/IEEE. "ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description. A Conceptual Model of Architecture Description." from http://www.iso-architecture.org/42010/cm/.

ISO/IEC/IEEE. "ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description. A Conceptual Model of Architecture Description." Retrieved 7 January, 2022, from http://www.iso-architecture.org/42010/cm/.

ISO/IEC/IEEE (2011). ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description.

Jiang, S., M. K. Natvig, S. Hallsteinsen and K. B. Lindberg (2022). Lessons Learned from Demonstrating Smart and Green Charging in an Urban Living Lab Accepted for: International Conference on Advanced Information Networking and Applications, Springer.

Junker, R. G., A. G. Azar, R. A. Lopes, K. B. Lindberg, G. Reynders, R. Relan and H. Madsen (2018). "Characterizing the energy flexibility of buildings and districts." Applied energy **225**: 175-182.

Natvig, M., R. S. Enrich, S. Jiang, S. Hallseteinsen and S. Venticinque (2021). "GreenCharge Project Deliverable: D5.4/D6.3 Intermediate Result for Innovation Effects Evaluation / Intermediate Evaluation Result for Stakeholder Acceptance Analysis."

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.

Netherlands Enterprise Agency (2019). "Electric vehicle charging. Definitions and explanation."

Netherlands Enterprise Agency (2019). Electric vehicle charging. Definitions and explanation.

Stav, E., S. Walderhaug and U. Johansen (2013). ARCADE An Open Architecture Description Framework. http://www.arcade-framework.org/.

Søråsen, R., P. Mork, K. B. Lindberg, Å. L. Hauge, F. J. Sund and G. Vollan (2019). "GreenCharge Project Deliverable: D2.3 Description of Oslo Pilot and User Needs."

Thema Consulting Group (2018). Descriptive study of Local Energy Communities THEMA Report 2018-20.

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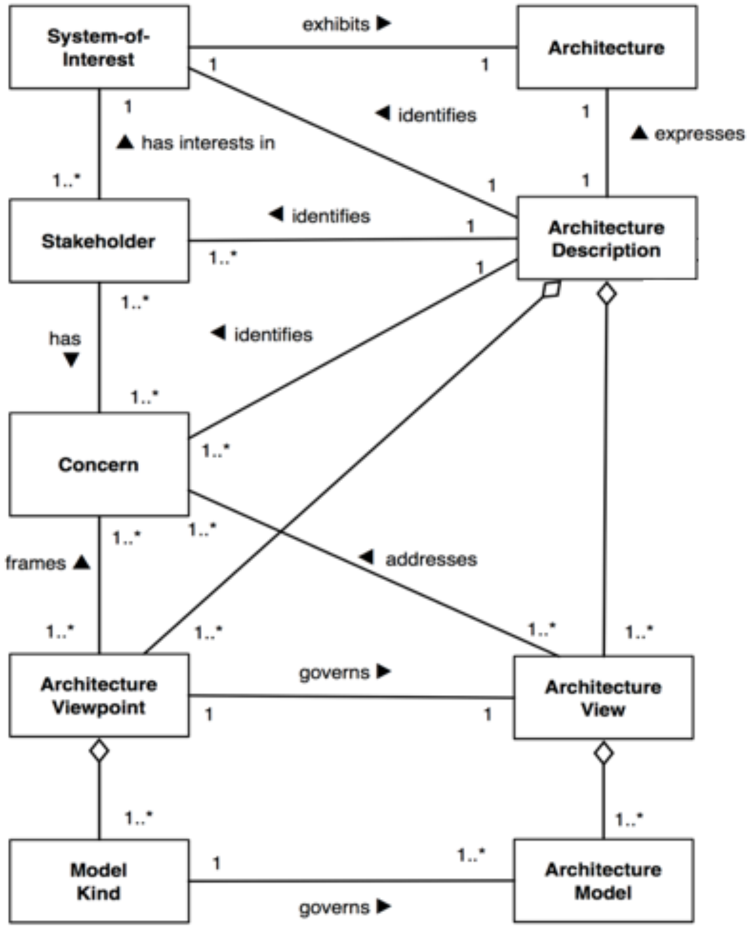
Annex A Architecture concepts

Two frameworks have guided the work on the GreenCharge reference architecture description:

- ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description (ISO/IEC/IEEE 2011), the successor of 1471-2000-IEEE. The specific subset of terms used is shown in the figure below, which also illustrates the relationships between the terms. Definitions of the terms are provided in the table below
- The ARCADE architecture description framework (Stav, Walderhaug et al. 2013). ARCADE is based on the standard 1471-2000-IEEE Recommended Practice for Architectural Description for Software-Intensive Systems (IEEE 2000), which is the preparatory standard for (ISO/IEC/IEEE 2011). ARCADE does, among others, suggest which viewpoints to use.



Terms and concepts of architecture descriptions and the relations between them (ISO/IEC/IEEE)

Definitions related to formal descriptions of architectures:

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Definition	Explanation
Architecture	Systems have architectures which are "fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution". The definition was chosen (1) to accommodate the broad definition of system: the architecture of X is what is fundamental to X (whether X is an enterprise, system, system of systems, or some other entity); and (2) to emphasize (via the phrase "concepts or properties") that a system can have an architecture even if that architecture is not written down.
Architecture description	An artefact that expresses an architecture. Architects and other system stakeholders use architecture descriptions to understand, analyse and compare architectures, and often as "blueprints" for planning and construction. An architecture description is a work product used to express the architecture of some system of interest. ISO/IEC/IEEE 42010 standard specifies requirements on architecture descriptions. An architecture description describes one possible architecture for a system of interest. An architecture description may take the form of a document, a set of models, a model repository, or some other form (the format is not defined by the standard).
Architecture model	An architecture view is comprised of architecture models. Each model is constructed in accordance with the conventions established by its model kind, typically defined as part of its governing viewpoint. Models provide a means for sharing details between views and for the use of multiple notations within a view.
Architecture view	An architecture view in an architecture description expresses the architecture of the system of interest from the perspective of one or more stakeholders to address specific concerns, using the conventions established by its viewpoint. An architecture view consists of one or more architecture models.
Architecture viewpoint	A set of conventions for constructing, interpreting, using and analysing one type of architecture view. A viewpoint includes model kinds, viewpoint languages and notations, modelling methods and analytic techniques to frame a specific set of concerns. Examples of viewpoints: operational, systems, technical, logical, deployment, process, information.
Component	See: software component.
Concern	Any interest in the system. The term derives from the phrase "separation of concerns" as originally coined by Edsgar Dijkstra. Examples of concerns: (system) purpose, functionality, structure, behaviour, cost, supportability, safety, interoperability.
Environment	In the context of an architecture description, the environment includes everything that is not a part of the system of interest system, and which interfaces the system of interest (i.e., our case the GreenCharge solution) directly. This includes both stakeholders and other systems. A system acts upon its environment and vice versa. A system's environment determines the range of influences upon the system. The environment is intended in the widest possible sense to include developmental, operational, technical, political, regulatory, and all other influences which can affect the architecture. These influences are categorized as concerns. Environment may also be the natural environment with all living and non-living things occurring naturally. The environment may also often refer to the overall condition of our planet, and how healthy it is, and how its sustainability is affected by human activity.
Model kind	Defines the conventions for one type of architecture model

Definition	Explanation
Reference use case	A reference use case defines the core functionality that should be addressed but may lack detailed functionality that may vary depending on the realisation. User interface functionality may for example not be included in reference use cases. A reference use case can be used as a blueprint to make a starting point for the definition of more detailed use cases to be implemented by real system components.
Software component	A unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third parties.
Subsystem	A coarse-grained component that can also be regarded as a system.
System of interest	A collection of components organized to accomplish a specific function or set of functions. A system of interest is situated in its environment, and the environment could include other systems. The system of interest is also referred to as GreenCharge solution.
Stakeholder	Individuals, groups or organizations holding concerns for the system of interest.
Use case	A use case describes how a system will be used and is a tool for modelling requirements of a system.
View	A representation of a whole system from the perspective of a related set of concerns
Viewpoint	A specification of the conventions for constructing and using a view. A pattern or template from which to develop individual views by establishing the purpose and audience for a view and the techniques for its creation and analysis.

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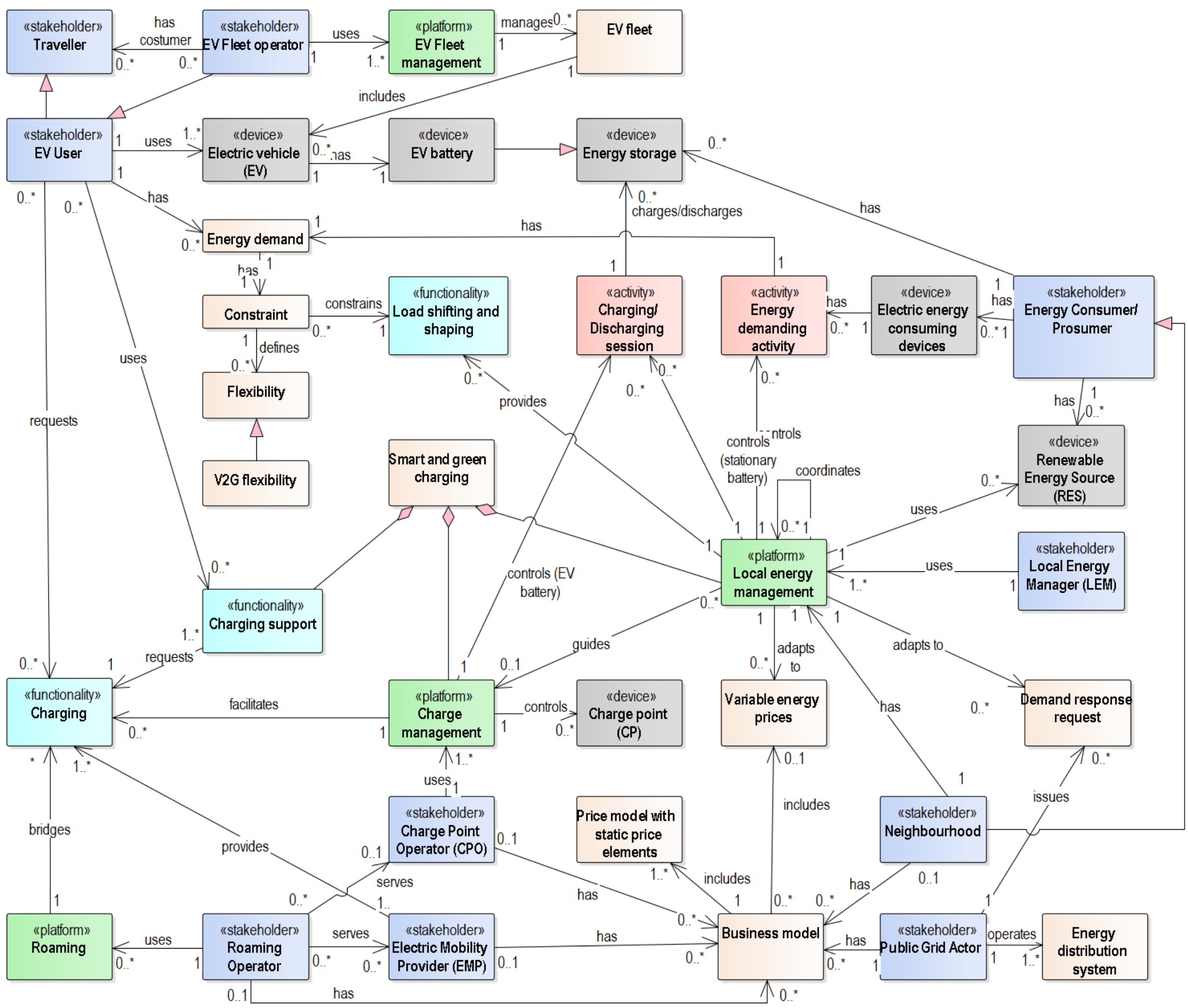
Annex B Domain model

The figure below depicts a domain model for smart and green charging. It defines the main concepts and terms the architecture description will build upon. A UML class diagram is used to represent the model.

Some of the concepts are of a certain category, as indicated by the stereotyping:

- The *stakeholder* stereotype indicates that the concept/term represents a stakeholder. These are further described in chapter 4.1.
- The *functionality* stereotype indicate that the concept is a functionality provided to a stakeholder from a digital system.
- The *activity* stereotype indicate that the concept is an activity that goes on for a certain time
- The *device* stereotype indicate that the concept is a physical piece of equipment, a device or a physical infrastructure.
- The *platform* stereotype indicate that the concept represents a software system which implement software services.



Smart and green charging includes *Charging support*, *Charge management* and *Local energy management*.

- An *EV User* uses, manually or automatically, a *Charging support* service to plan and request *Charging* of an *Electric Vehicle (EV)*. The *Charging* service is provided by an *Electric Mobility Provider (EMP)*.
- A *Local Energy Manager (LEM)* uses a *Local energy management* platform to control the energy use, production, and storage in a *Neighbourhood. The* energy import is adapted to *Demand response requests* issued by *Public Grid Actors* operating the *Energy distribution system*.

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The *Local energy management* may be hierarchical – different platforms may manage different parts of the neighbourhood, and the *Local energy management* for the Neighbourhood as a whole may coordinate its decisions with other *Local energy management* systems. The *Neighbourhood* is an extension of the *Energy Consumer/Procumer* stakeholder and may have *Electric energy consuming devices*, stationary *Energy storages*, and *Renewable Energy sources (RES)*.

- A Charge Point Operator (CPO) uses a Charge management system to control Charge points (CPs) and the Charging/Discharging sessions that charges/discharges the EV batteries. The Charge management may control the sessions according to guidelines received from a Local Energy Management system.

Roaming Operators use *Roaming* platforms to bridge charging provided by different *Electric Mobility Providers (EMPs)* and *Charge Point Operators (CPOs)* to facilitate the use of *Charging* services regardless of subscriptions.

Energy demands originate from *EV users* (due to a charging requests) and *Energy Consumers/Procumers*. *Energy Consumers/Procumers* have *Electric Energy consuming devices* with *Energy demanding activities* causing *Energy demands*. An *Energy demand* has *Constraints* defining the energy request and may provide *Flexibility* with respect to when de energy is needed. In case of a charging request, V2G flexibility may also be provided.

The *Local energy management* provides *Load shifting and shaping* to optimise the use of *Energy storage* and *Renewable Energy Sources (RES)* and to fulfil *Energy demands* according to associated *Constraints*.

Stakeholders such as the *Roaming Operator*, the *Electric Mobility Provider (EMP)*, the *Charge Point Operator (CPO)*, and the *Public Grid Actors* may have *Business models*, and these may include the use of *Price lists with static price elements* for different products and services. *Business models* of *Public grid actors* such as energy retails may also include the use of *Variable energy prices*. *Neighbourhoods* may also have business models and price models, e.g., for internal sales of energy from *Renewable Energy Sources (RES)* among *Energy Consumers/Procumers* in the neighbourhood.

A *Traveller* may be a customer of an *EV Fleet Operator*. The *EV Fleet Operator* does *EV fleet management* to manage an *EV fleet* that includes *Electric vehicles (EVs)*. When the *EV Fleet Operator* offers EVs to Travellers, the Traveller becomes and *EV User*. When the EV Fleet Operator needs charging of electric vehicles in the EV Fleet, the EV Fleet Operator also becomes an *EV User*.

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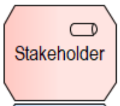
Annex C Notations used

This annex provides an overview of the notations used in the architecture models

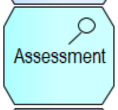
C.1 Motivation diagram notation

The following model elements are used in the ArchiMate motivation models:

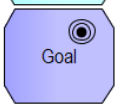


Stakeholder type addressed. See definitions of stakeholder types in Chapter 4.1.

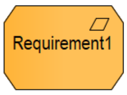
Driver that motivates the stakeholder to change in a way that facilitate a transition towards sustainable eMobility.



Assessment of the current situation with respect to a Driver, i.e., a barrier to overcome.



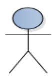
Goal that must be met to overcome a barrier and to meet a Driver.



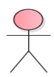
Overall requirement derived from one or more goals.

C.2 Use case notation

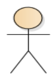
The model elements used in the use case diagrams are:



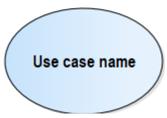
Primary stakeholder taking initiatives.



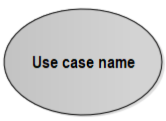
Secondary stakeholder responding to the initiatives of the primary stakeholders.



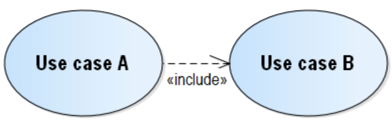
External stakeholder not involved in the GreenCharge solution but contributing to the solution.



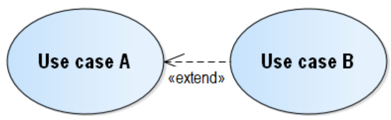
Use case in the depicted use case diagram that is further described by the text below the diagram.



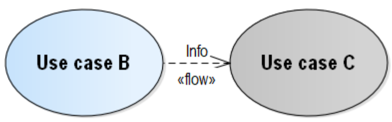
Use case that is outside the scope of the depicted use case diagram. The use case is not described by the text below the diagram. The use case is however decomposed and described in another diagram.



The association with the «include» stereotype indicates that Use case B is a part of Use case A.



The association with the «extend» stereotype indicates that Use case A in some cases is extended by Use case B.



The association with the «flow» stereotype indicates that the association is an information flow from Use case B to Use case C. Such flows may also be bi-directional. Information flows are just used to/from and between the overall use cases depicted in Figure 6.

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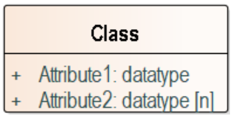
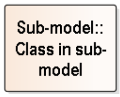
C.3 Information model notation

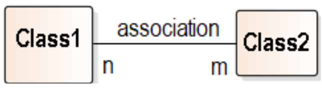


Information class with two attributes with datatypes. Attribute2 has multiplicity n. n may for example be:

- A number: The attribute is an array with n elements
- 1..n: The attribute may have 1 up till n elements
- 0..1: The attribute is optional.
- 0..n: The attribute is optional and may have up till n elements

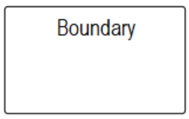


Information class in another sub-model. The <sub model> string is the name of the sub-model.



Association between two information classes. M and n are the cardinality, i.e., how many instances that are allowed. The cardinalities may for example be the following for n:

- 1: Class2 always has a relation to just one Class1
- 0..1: Class2 may have a relation to none or one Class1
- 0..*: Class2 may have a relation to none or many Class1
- 1..*: Class2 may have a relation to one or many Class1



Boundary. A class inside the boundary belongs to the sub-model. A class outside the boundary belongs to another sub-models.

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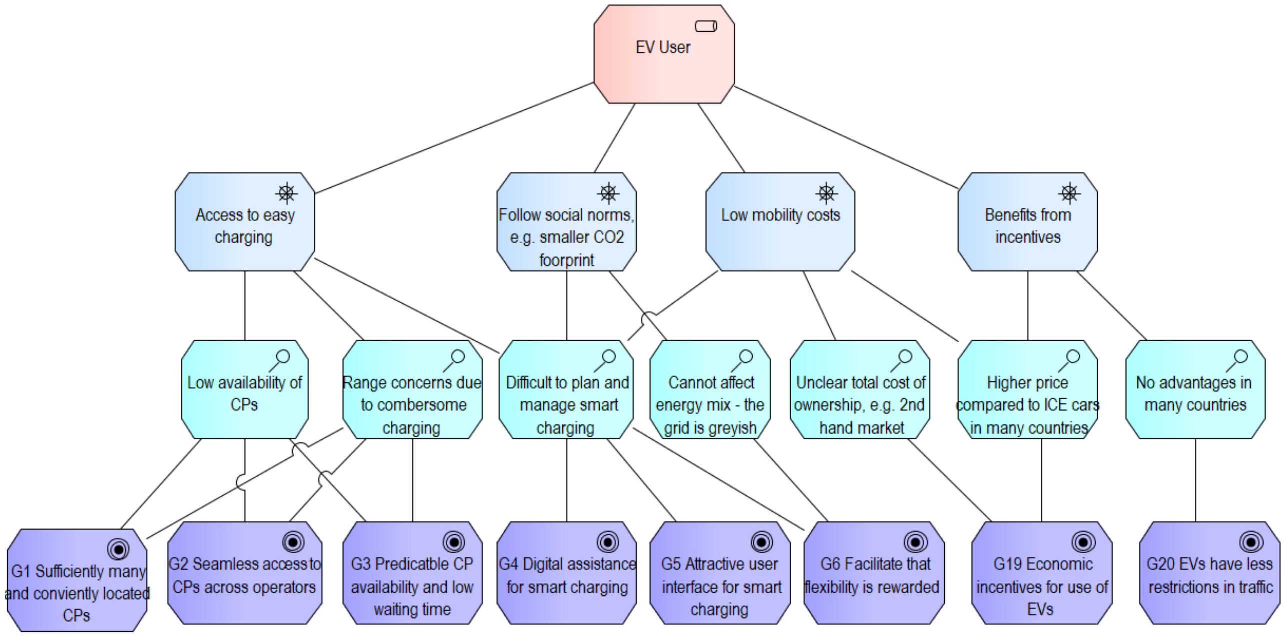
Annex D Motivation models

The overall concerns of the stakeholder types addressed in Chapter 4.1 are analysed through a structured approach guided by ArchiMate motivation models. The focus is on the need for changes (towards eMobility and sustainable behaviour), and for each stakeholder type the motivations for changes are identified and analysed. The notation used to define the models is defined in B.1.

The drivers, assessments and goals of each stakeholder type are described below. The notation used is defined in B.1. A complete list of the goals identified is provided in section 1.1. These goals are the starting point for the overall requirements defined in Chapter 6.

Use of this model as a blueprint in system architecture descriptions: The stakeholders of relevance must be identified, and the associated motivation diagrams provide an overview of relevant concerns for these stakeholders. The diagrams should however be refined based on specific issues related to the actual system.

D.1 EV User motivation model



The drivers and assessments associated to the EV User motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of the current situation
Access to easy charging The inconvenience of charging is minimised.	**Low availability of CPs** EV Users cannot expect to get their electric vehicle (EV) charged when charging is needed, and the access to charging is not reliable and predictable. The reasons may for example be: • charge points are not located where they are needed. • charge points cannot be used because the EV User does not have a business agreement with the point operator • charge points may be occupied, and the waiting time is too long.
	Range concerns due to cumbersome charging On a journey, EV Users experience uncertainty with respect to access to charging when charging is needed. The EV Users have concerns because: • Manual charge planning is needed to find a charge point that can be used and is located when and where charging is needed.

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	• Extra waiting time might be required if the charge point is occupied.
	Difficult to plan and manage smart charging With smart charging, the EV User cannot just plug in the electric vehicle and leave it. Extra effort must be used on • Manual charge planning (where to charge, when to charge and how to get the best energy price) • Specification of the charging demand (when the electric vehicle should be charged and how much it should be charged) and other parameters that are needed when the smart charging is planned and managed. Today • There is no or limited communication with charge service to get information on availability of charge points, energy costs, etc. In case of communication, eMobility Provider (EMP)s cannot be approached in a digital, common way. • The EV User must start the charging immediately, or the charging must be configured manually via the interface provided by the electric vehicle manufacturer. In case of the latter of the configuration is not an informed decision. The EV User for example does not know when the energy is cheapest.
Follow social norms, e.g., smaller CO2 footprint EV Users want to be green	**Difficult to plan and manage smart charging – see above**
	Cannot affect grid mix – Energy mix is greyish The positive effect of e-mobility on the environment depends on the energy mix used for charging. The EV User can however not affect energy mix in the grid in European countries. The charging must be accomplished with the energy mix provided by the Public Grid Actor, and currently the mix is not completely green (the CO2 intensity varies between countries).
Low operational cost The charging costs are reduced	**Difficult to plan and manage smart charging – see above**
	Unclear total cost of ownership, e.g., 2nd hand market
	Higher price compared to ICE cars in many countries This is currently the case in most European countries (there are however countries where EV Users receive huge economic benefits).
Benefits from incentives The use of electric vehicles is more advantageous than the use of fossil cars	**Higher price compared to ICE cars in many countries – see above**
	No advantages in many countries Today, there are no incentives use of electric vehicles in many countries. They have no advantages in traffic and no economic benefits.

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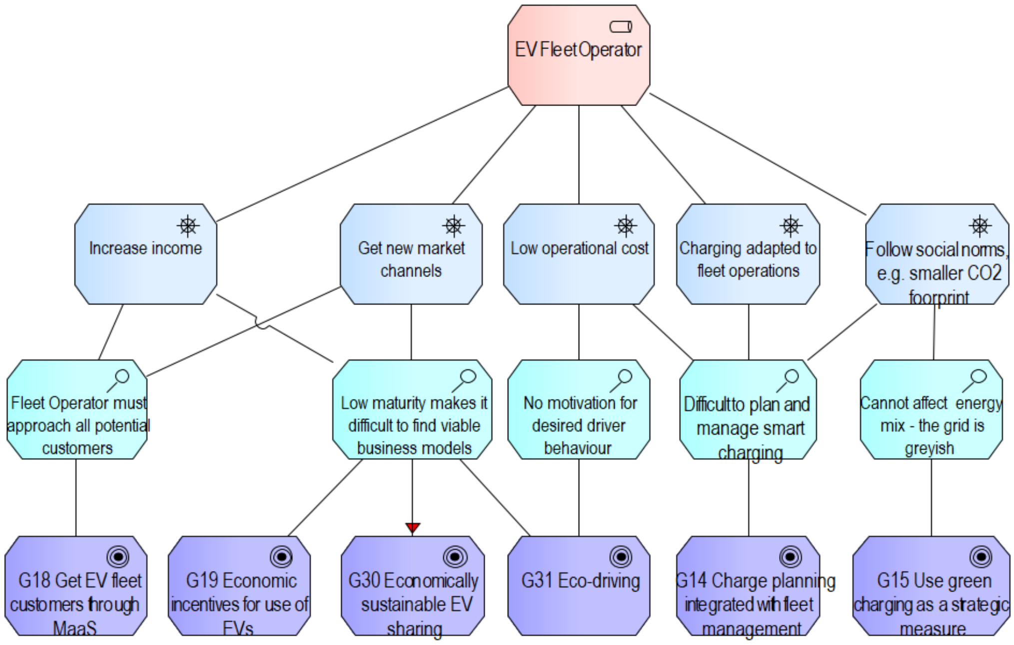
D.2 EV Fleet Operator motivation model



The drivers and assessments associated to the EV Fleet Operator motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of the current situation
Increase income	**Fleet Operator must approach all potential customers** It is time consuming to identify new customer groups and to do marketing towards such groups. Today the Fleet Operator must find the appropriate market channels and approach the potential customers through these channels. The Fleet Operator may also have to provide specific tools for interaction with new customer groups (e.g., new apps).
	Low maturity makes it difficult to find viable business models In some countries, the e-mobility maturity is low, and thus it is challenging to find viable business models and enough users. More knowledge is needed both by the EV fleet operators and the cities on opportunities, the policy needed (e.g., subsidises) and other aspects that can arrange for sustainable services.
Get new market channels EV Fleet Operators need new customers that they cannot reach today.	**Fleet Operator must approach all potential customers – See above.**
	Low maturity makes it difficult to find viable business models – See above.
Low operational costs	**No motivation for desired driver behaviour** The customers am not motivated for the desired driving style, e.g., eco-driving. Such a driving style will reduce the need for charging and cause less wear that a more traditional driving style-
	Difficult to plan and manage smart charging The planning of fleet operations is complicated due to the charging. Time for charging must be accounted for. – See also description in C.1

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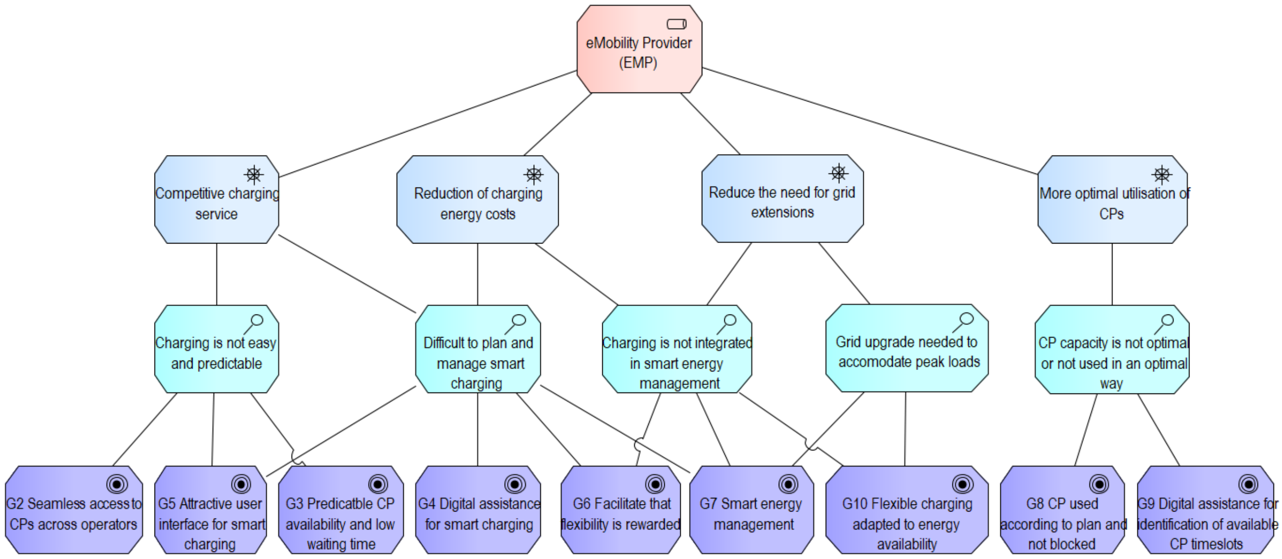
Charging adapted to fleet operations The charging complicates the fleet operations. Support for adaption of charging to fleet operations is needed.	**Difficult to plan and manage smart charging –** see above.
Follow social norms, e.g., smaller CO2 footprint The emissions from use of electric vehicles (EVs) are reduced	**Difficult to plan and manage smart charging – see above**
	Cannot affect grid mix – Energy mix is greyish The Fleet operators cannot affect energy mix in the grid. The charging must be accomplished with the energy mix provided by the Public Grid Actor, and currently the mix is not completely green (the CO2 intensity varies between countries).

D.3 eMobility Provider (EMP) motivation model



The drivers and assessments associated to the eMobility Provider (EMP) motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of the current situation
Competitive charge service New and attractive features can be provided	**Charging is not easy and predictable** Charge services do not support the EV User in charge planning, do not reduce waiting times and do not provide predictability regarding the access to charge points.
	Difficult to plan and manage smart charging It is challenging to offer services for smart charging. See description in C.1.
Reduction of charging energy costs Costs can be reduced through smart charging	**Difficult to plan and manage smart charging - see above**
	Charging is not integrated in smart energy management Smart charging will have positive effects on energy use (reduce peaks, etc.), but today such solutions are not available there are no incentives for smart charging.
Reduce the need for grid extensions	**Charging is not integrated in smart energy management – see above**
	Grid upgrade needed to accommodate peak loads Unmanaged charging may cause high peak demands that exceed the capacity of the local grid, for example when people come to work at the same time and connect their

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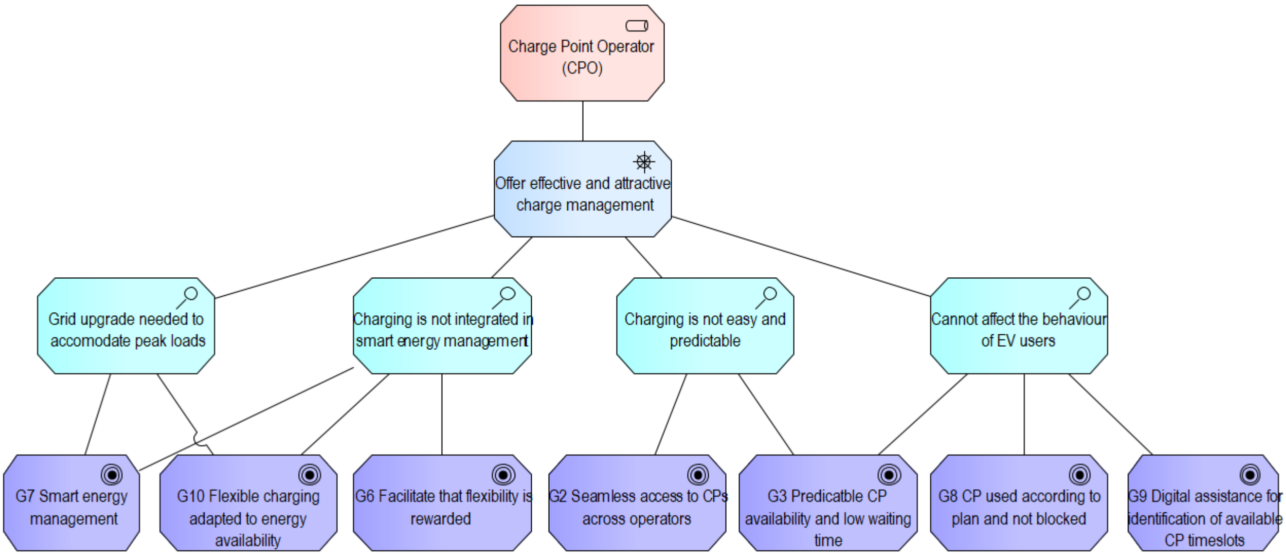
	electric vehicles for charging, and similarly when they return home in the afternoon. With unmanaged charging, expensive grid strengthening is required.
More optimal utilisation of CPs The use of charge points can be managed in way that increase the profit	**CP capacity is not optimal or not used in an optimal way** The profit may be reduced due to • Too low charge point capacity. charge points are so overbooked that EV Users chose to use/book charge points provided by other Charge service Providers. • To high charge point capacity. Most of the time, charge points are not used. • charge points are blocked by fully charged electric vehicles that do not leave the charge point when the charging is completed

D.4 Charge Point Operator (CPO) motivation model



The drivers and assessments associated to the Charge Point Operator (CPO) motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of the current situation
Offer effective and attractive charge management It is a market advantage to offer better charging solutions	**Grid upgrade needed to accommodate peak loads** Unmanaged charging may cause high peak demands that exceed the capacity of the local grid, for example when people come to work at the same time and connect their electric vehicles for charging, and similarly when they return home in the afternoon. With unmanaged charging, expensive grid strengthening is required.
	Charging is not integrated in smart energy management The charge management does not accommodate smart energy management. For example, the charging of individual electric vehicles cannot be started and stopped or distributed over time to arrange for adaption to energy availability.
	Charging is not easy and predictable Charge management does not support services that support the EV User in charge planning, reduce waiting times and provide predictability regarding the access to charge points.
	Cannot affect the behaviour of EV Users

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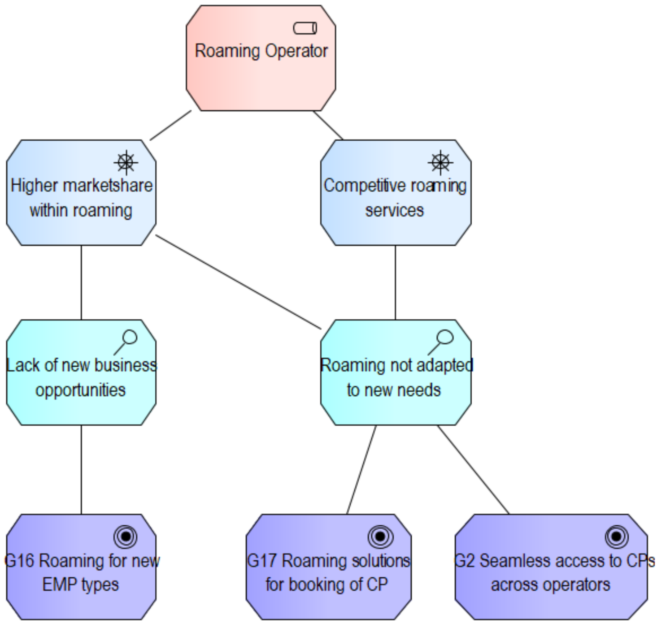
	Charge management does not influence which charge points the EV Users connects to and the time the electric vehicle is connected to the charge point. Blocking of charge points by fully charged electric vehicles cannot be avoided.

D.5 Roaming Operator motivation model



The drivers and assessments associated to the Roaming Operator motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of the current situation
Higher market share within roaming	**Lack of new business opportunities** Roaming is not used related to new charge services (e.g., sharing of private charge points and shared use of dedicated charge points).
	Roaming not adapted to new needs The roaming of booking of charging is implemented but not used by the CPO. The booking of energy (needed for smart charging) is neither implemented nor supported by CPOs.
Competitive roaming services	**Roaming adapted to new needs - see above**

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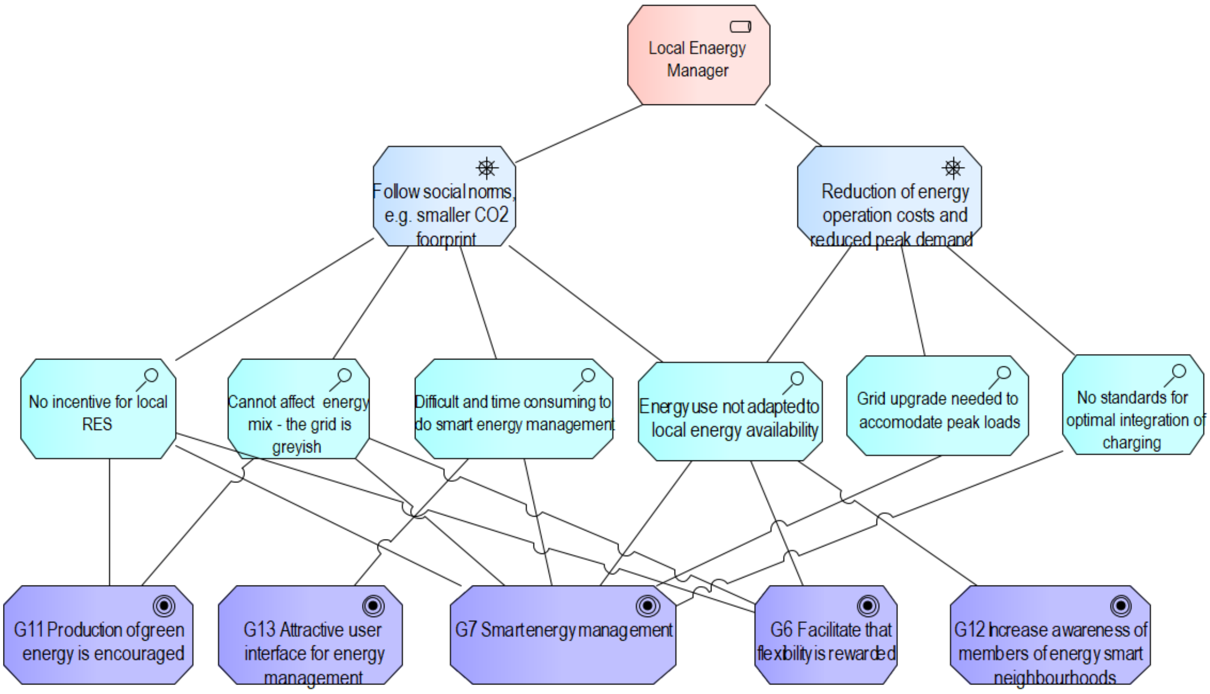
D.6 Local Energy Manager motivation model



The drivers and assessments associated to the Local Energy Manager motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of current situation
Follow social norms, e.g., smaller CO2 footprint The Local Energy Manager represents property owners that want to be green	**No incentive for local RES** Today, short term return of investments on local renewable energy sources cannot be expected.
	Cannot affect grid mix – Energy mix is greyish The current energy mix in the public grid is grey.
	Difficult and time consuming to do smart energy management Smart energy management may reduce the CO2 footprint, but it is difficult to do this without automatic support from digital solutions.
	Energy use not adapted to energy availability Today, the energy use cannot be adapted to the energy availability, e.g., the use of energy cannot be configured to adapt to the availability of green energy or the energy tariffs.
Reduction energy operation costs and reduced peak demand The Local Energy Manager represents property owners that want to reduce their energy related costs	**Energy use not adapted to energy availability** – see above.
	Grid upgrade needed to accommodate peak loads Unmanaged charging may cause high peak demands that exceed the capacity of the local grid, for example when people come to work at the same time and connect their electric vehicles for charging, and similarly when they return home in the afternoon. With unmanaged charging, expensive grid strengthening is required.
	No standards for optimal integration of charging Interfaces for integration and facilitation of smart and green charging do not exist, and "plug and play" is not possible. Thus, it is challenging to integrate smart charging with the local energy management. The integration must be designed and implemented, and problems may arise.

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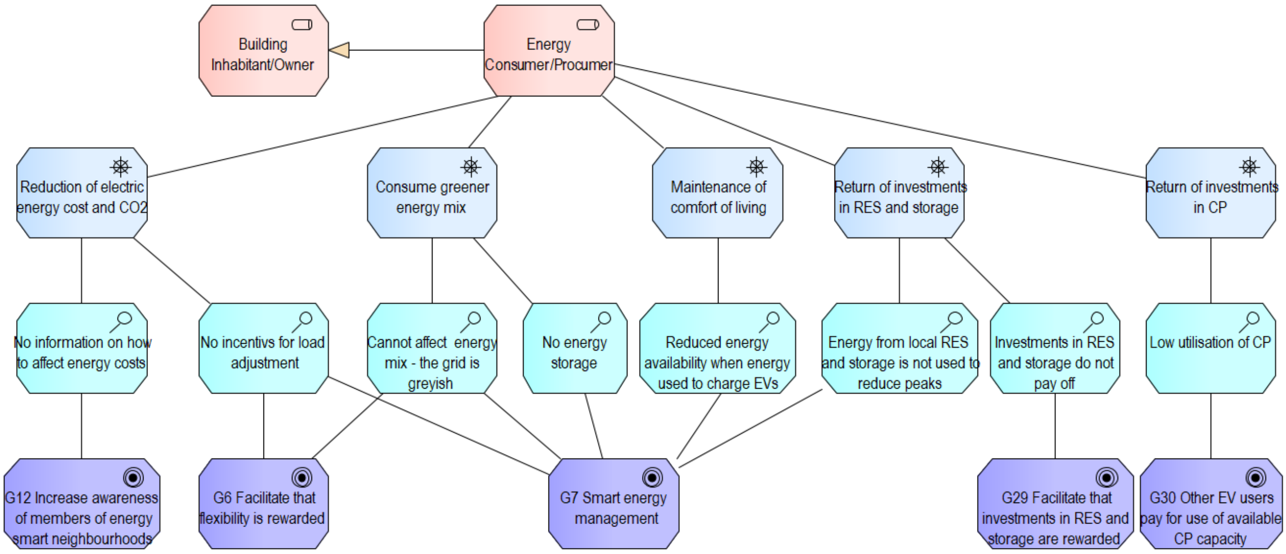
D.7 Energy Consumer/Prosumer motivation model



The drivers and assessments associated to the Energy Consumer/Procumer motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of current situation
Reduction of electric energy costs Energy Consumer/Prosumers want to reduce their costs	**No information on possible measures and effects** Energy Consumer/Prosumers do not know how to reduce their energy costs in a way that does not affect their comport of living.
	No incentives for adaption to energy availability An adaption of energy use to energy availability will have positive effects on peaks, but today there are no incentives for such actions.
Consume greener energy mix	**Cannot affect grid mix – Energy mix is greyish** – See description in C.1 The positive effect of e-mobility on the environment depends on the energy mix used for charging. The charging must be accomplished with the energy mix provided by the Public Grid Actor, and currently the mix is not completely green (the CO2 intensity varies between countries).
	No energy storage Locally produced renewable energy may not be used in an optimal way in periods when the production is high, and the consumption is low. When no energy storage is available
Maintenance of comfort of living Reduction of energy use is accepted if the comfort of living is not affected.	**Reduces energy availability when energy is used to charge EVs** The energy supply might be affected if many electric vehicles (EVs) are charged at the same time. Such situations might cause instability in the grid and a reduction of the service level.
Return of investments in RES and storage	**Energy from local RES and storage is not used to reduce peaks** It is not common to use local energy production in an optimal way to reduce peak loads.
	Investments in RES and Storage do not pay of The investments are high and usually they do pay of unless used in very many years.
Return of investment in CP	**Low utilisation of CP** Private charge points are not used all the time, and the owner must cover all the costs.

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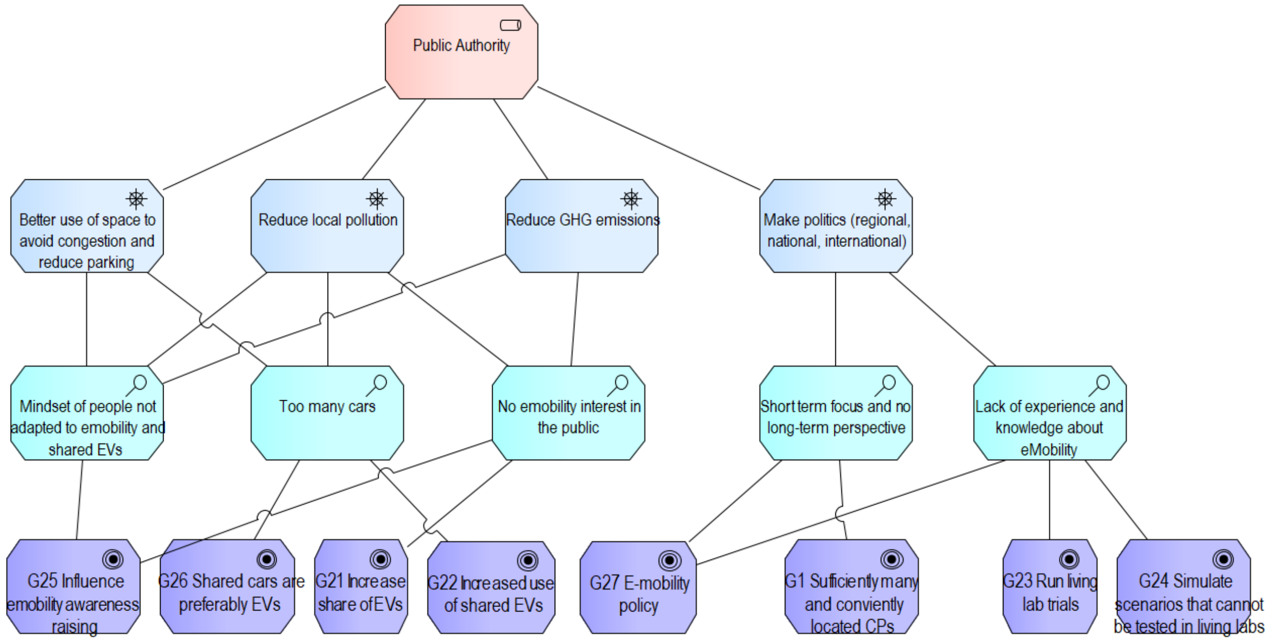
D.8 Public Authority motivation model



The drivers and assessments associated to the Public Authority motivation model are described in the Figure above and described in the Table below. The goals are described in Table 2 in section 4.2.

Driver	Assessment of current situation
Better use of space to avoid congestion and reduce parking	**Mindset of people not adapted to emobility and shared EVs** In many countries, citizens believe that electric vehicles (EVs) cannot fulfil their transport demands, and they prefer to own a car that can fulfil all transport demands. They do not consider using a shared electric vehicle in combination with other transport services.
	Too many cars Citizens prefer to own a car rather than to use a shared car.
Reduce local pollution	**Mindset of people not adapted to emobility and shared EVs – see above**
	Too many cars – see above
	No emobility interest in the public Citizens are not aware of the positive aspects of electric vehicles.
Reduce GHG emissions	**Mindset of people not adapted to emobility and shared EVs – see above**
	No emobility interest in the public – see above
Make policies (regional, national, international)	**Short term focus and no long-term perspective** The policy must address charging solutions that are scalable, both with respect to charging infrastructure and energy issues.
	Lack of experience and knowledge about emobility The policy must address the lack of knowledge and awareness of emobility

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