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GreenCharge Project Deliverable: D4.1

Initial 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 around, but money makes the world go around. 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 charge station or within a neighbourhood, battery swapping), and *charging support* (booking, priority charging).

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

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

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

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

For more information

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Executive Summary

This deliverable is the initial 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 is a person or a legal entity using one or more electric vehicles. The EV Users wants predictable access and high availability of charge points and low mobility costs, as well as assistance for smart charging.
- **eMobility Provider (EMP).** The EMP provides electric vehicle charge services to EV Users. The EMP wants the provide competitive and attractive charge services, reduction of charging energy costs, optimal utilisation of charge points and low investments costs in grid infrastructures.
- **Charge Point Operator (CPO).** The CPO is responsible for the provisioning and operation of the charging infrastructure and for managing electricity to provide requested energy transfer services. The CPO wants effective and attractive charge management that can facilitate charging adapted to energy availability and end user services that rewards flexible charging and provides predictable charge point access.
- **Roaming Operator.** The Roaming Operator facilitates authorisation, billing and settling procedure for electric vehicle charge service roaming, between two roaming endpoints (operated by EMPs and/or CPOs). The Roaming Operator aims for competitive roaming services.
- **Local Energy Manager (LEM).** The LEM manager aims for optimal use of locally produces green energy and manages the use and storage of energy in a local energy community or a part of such a community (building, neighbourhood, charging infrastructure, etc.). Energy demanding activities, charging included, are planned and controlled dependent on current and foreseen energy demands and energy availability.

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. It describes the functionality needed by a decomposition into detailed use cases. 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 and related information exchange. The overall concerns of the stakeholders are used as a starting point, and the detailed requirements are derived from use cases and other sources.
- 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 identifies interfaces and messages used for communication, and a system collaboration model defines the interactions.
- The **distribution and the realisation views** are not defined since the reference architecture description does not define the physical realisation of the solution into components.

To ensure the necessary openness, the reference architecture has generic specifications and is modelled as a set of services collaborating through message exchange, The implementation onto underpinning systems is left to each deployment. All the architecture views listed above have guidelines describing how this can be done.

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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.
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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Lists of Definitions

This document makes use of some terminology that may be new to some readers. The two separate lists below are primarily intended as a source of ***reference*** – you can look up terms that you may find unfamiliar.

The reason for two separate lists is that the terms fall into two distinct groups: (1) terms about formal descriptions of architectures; and (2) terms about energy management / eMobility. If one or other of these is unfamiliar to you, perhaps a quick scan of the definitions might work as an express "tutorial" for you on the topic.

Table 1: Definitions related to formal descriptions of architectures

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.

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Definition	Explanation
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
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.

Table 2: Definitions related to energy management and eMobility

Definition	Explanation
Charge management	The charge management is done by a 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.

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Definition	**Explanation**
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 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).
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.

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Definition	Explanation
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.
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 initial version of the GreenCharge reference architecture description and provides generic and holistic specifications for ICT solutions for smart and green charging. It will serve as a blueprint for the realisation at the GreenCharge pilot sites in Oslo, Bremen and Barcelona but the specifications are generic and may also be used outside the GreenCharge project (see section 2.1 for more details on reference architectures).

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

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.

The deliverable has two sections providing an introduction (section 1 and 2). The other sections are the actual architecture description. The boxes in Figure 1 provides an overview, and the sections are categorised according to the degree of technical competence we assume is needed by the readers (see legend in figure). (Further details on the actual content are provided in section 2.2.)

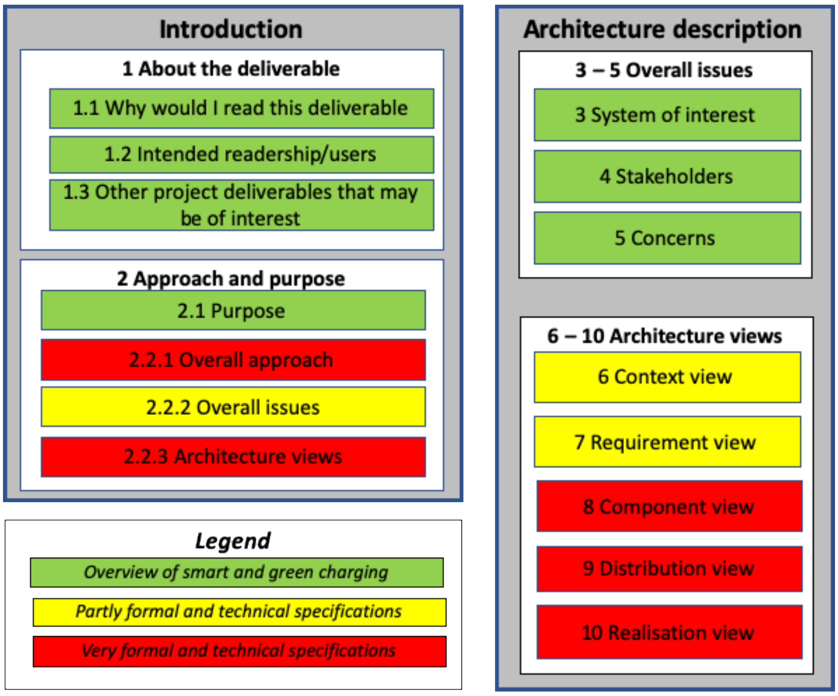

Figure 1 Categorisation of the sections in the deliverable

In the introduction box in Figure 1, the green sections provide an overview of the deliverable and the purpose of it. In the architecture description box, the green sections provide an overview of the GreenCharge concept.

The yellow sections 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.

The red sections are very formal and technical specifications targeting readers doing technical design and development of software solutions.

Participants in the GreenCharge project should in general read the green parts to get an overview of smart and green charging and the motivations and needs of stakeholders involved. They should also read the yellow context view to get a common understanding of the functionality required and how the functionality fits into a larger context. In particular:

- **The pilot owners in GreenCharge** should use the yellow context view to define the scope of the local pilots, and in addition they should read the yellow requirement view to get input on overall requirements that are to be prioritised and further elaborated into detailed requirements for the local implementations.
- **The system designers and software developers in the GreenCharge project** should use the views mentioned above as well as the red component view to design and realise the technical solutions. In addition, they should use the guidelines provided in the red distribution and realisation views to do the design of the physical system components.

Other stakeholders with interest in smart and green charging can read the green parts of the deliverable to get an overview. In addition, other views may be of interest.

- **Users of charging services or buyers of charging services/products** (e.g. property owners, housing cooperations, employers, fleet operators, etc.) may get a better understanding of the green and smart charging opportunities and thereby get in a better position when services/products are chosen/purchased. They may for example use the yellow context and the yellow requirement views to get input on which functionality they should request.
- **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) can 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, services or products and the red component view to get further input on the realisation.

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.

- The *use case model* in section 6.1 builds upon the description of the Green Charge pilots:
  - D2.3 Description of the Oslo Pilot.
  - D2.9 Description of the Bremen Pilot
  - D2.16 Description of the Barcelona Pilot
- The *requirements view* in chapter 7 is among others based on
  - D2.4/D2.10/D2.17 Implementation plan for the Oslo/Bremen/Barcelona Pilot. These deliverables define overall requirements for each pilot site.
  - D5.1/D6.1 Evaluation Design / Stakeholder Acceptance Evaluation Methodology and Plan. This deliverable provides input regarding the data needed for evaluations and simulations.
  - D3.2 Initial version of the business models. This deliverable defines the basis for requirements regarding the technical support to the realisation of business models.
- The *system information model* in section 8.1 is among others based on:
  - D5.1/D6.1 Evaluation Design / Stakeholder Acceptance Evaluation Methodology and Plan. These deliverables provide input on the data needed for evaluations and simulations.

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

- D4.3 Initial version of Integrated Prototypes. 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: This deliverable depends on automated data collection from the pilot sites, and the data collection will be accomplished as described in D4.1.
- D5.4 Intermediate Result for Innovation Effects Evaluation: This deliverable depends on automated data collection from the pilot sites, and the data collection will be accomplished as described in D4.1.

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 **GreenCharge concept** 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.

The electric energy supply sector is a mature and highly regulated sector with a well-established structure and supporting technical systems and 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.

Therefore, 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*.

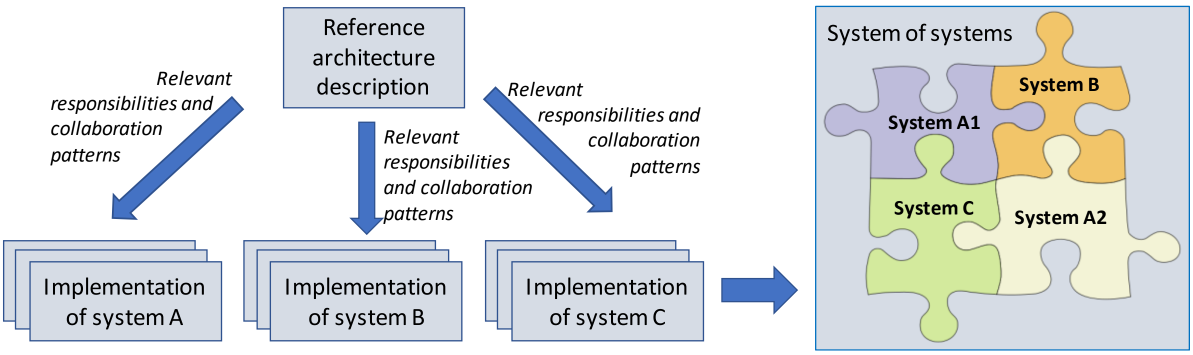

Figure 2 The role of a reference architecture description

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.

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.

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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.

2.2 Reference architecture description content and approach

The ARCADE architecture description framework (Stav, Walderhaug et al. 2013) has guided the work on the reference architecture description. ARCADE is based on the standard 1471-2000-IEEE Recommended Practice for Architectural Description for Software- Intensive Systems (IEEE 2000).

The architecture description uses a subset of terms and concepts defined in the standard *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 below in Figure 3, which also illustrates the *relationships between* the terms. *Definitions* of the terms are provided in Table 1 on page 8.

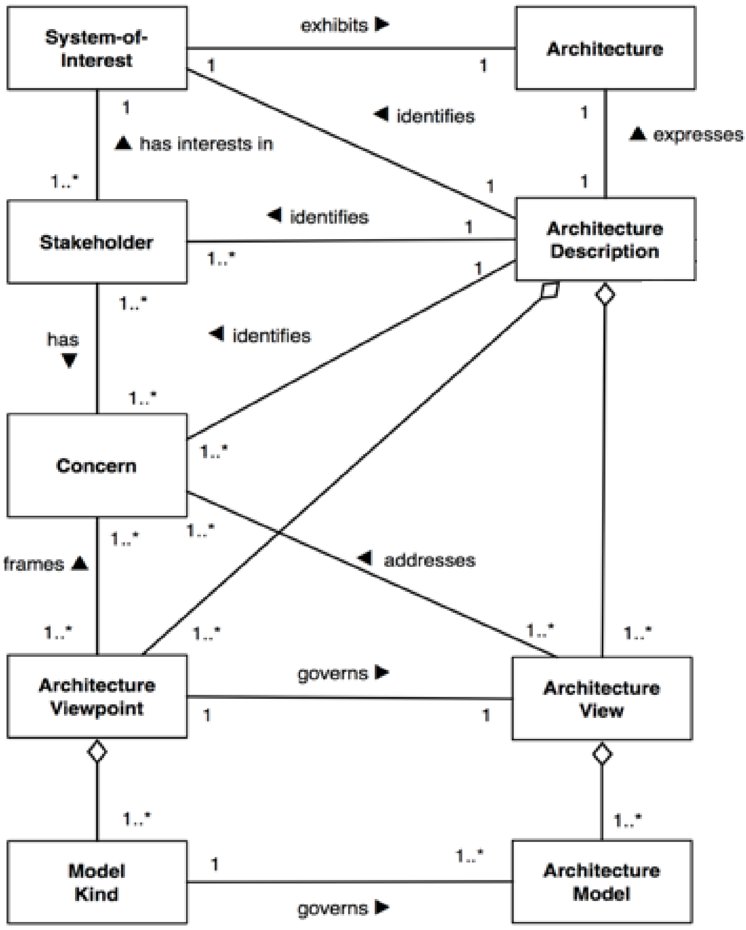

Figure 3 Terms and concepts of architecture descriptions and the relations between them (ISO/IEC/IEEE)

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The relevant terms and concepts used from ISO/IEC/IEEE 42010 are: System of interest, architecture, architecture description, stakeholder, concern, architecture viewpoint, architecture view and architecture model (the others are not further addressed). They are defined in the List of Definitions on page 8 and their relations are depicted in Figure 3.

2.2.1 Overall approach

The content of the GreenCharge reference architecture description is depicted in the Figure 4 together with overall information on the input that contributed to the different parts of the architecture description.

The selection of viewpoints and the content of the selected views are guided by:

- 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.
- The focus on system integration. 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.

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 and the domain knowledge (knowledge on existing solutions included) in the project consortium (established before the start of the project) as well as knowledge, 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.
- Parts of the architecture provided a starting point for or input to the work in other parts of the architecture.

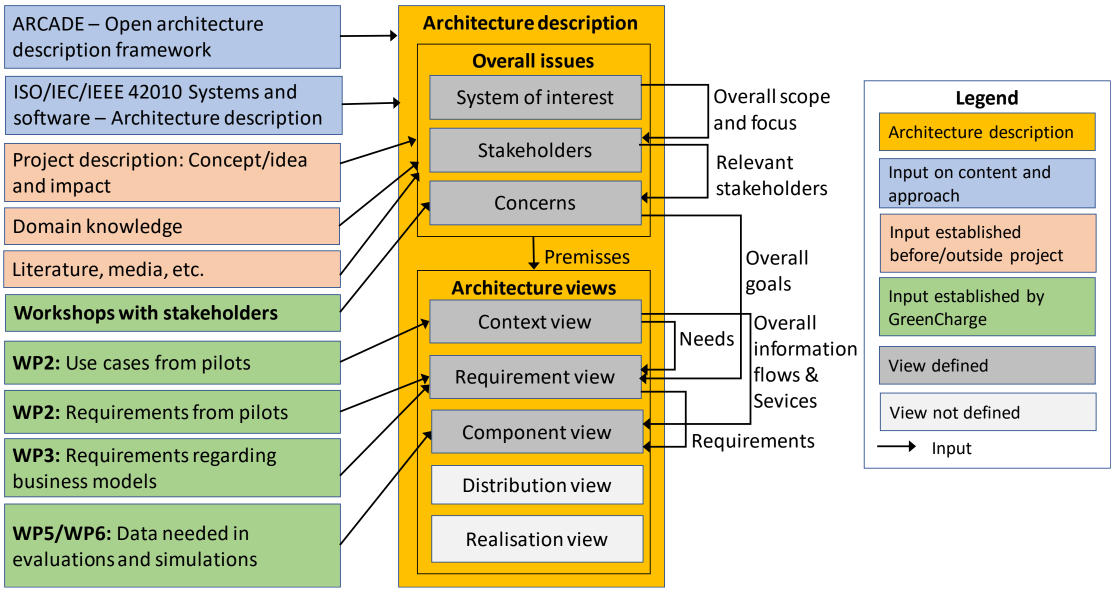

Figure 4 GreenCharge reference architecture description content and approach

More details are provided in the next sections. A comment on how the view/model is to be used when the reference architecture description is used as a blueprint is also added for each view or model.

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.

2.2.2 Overall issues

As depicted in the overall issues box in Figure 4, the system of interest, the stakeholders holding concerns for the system of interest and the concerns of these stakeholders are identified and described in the architecture description.

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). In addition, the following models are used to define the system:

- *Overall use case model* expressed by UML 2.0 use case diagrams. The model defines the overall functionality to be supported by the system.
- *Domain concept model* expressed by UML 2.0 class diagrams. The model defines important concepts and terms used in the specification of the system of interest (i.e. the reference architecture description) and the relations between the concepts and terms.

Stakeholders: The stakeholder types of relevance were 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 pre-release of IEC 63119-1 (IEC 2019) and reports (Netherlands Enterprise Agency 2019). The project consortium also holds considerable domain knowledge that was used to identify the relevant stakeholder types.

Concerns: 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. The following model is used to express the concerns of the stakeholder types:

- *Motivation model* expressed by Archimate motivation model elements[1] (Aldea, Iacob et al. 2015) were used to analyse and document the concerns and to identify goals to achieve to overcome barriers.

2.2.3 Architecture views

The reference architecture description defines the architecture views according to the conventions defined by the viewpoints (see the architecture views box in Figure 4). The selected viewpoints are further described below with references to the use of models.

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).

Context viewpoint: The aim is a common understanding of the GreenCharge solution and to define how the solution should work at a functional level. The architecture models used to describe the context view are:

- *Use case model* expressed by UML 2.0 use case diagrams. The model defines the required functionality.
- *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.
- *Environmental model* expressed by UML 2.0 component diagrams. The model defines the external components which the GreenCharge solution may interact with.

Requirement viewpoint: The aim is to specify requirements regarding different aspects of the solution. However, since this is a reference architecture description, the requirements addressed are not very detailed.

[1] http://pubs.opengroup.org/architecture/archimate3-doc/chap06.html

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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 architecture model used to describe the requirement view is:

- *Motivation model* expressed by Archimate motivation elements. The model defines the overall requirements derived from the concerns of the stakeholders. 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: The aim is to address how the logical components, i.e. the services identified in the context view, collaborate and interact. This includes both the definition of the information exchanged and the definition of when and how the information is exchanged. The architecture models 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.

Distribution and realisation viewpoints: These viewpoints are not defined by the reference architecture description since the realisation in physical system components is not decided by the reference architecture. The distribution and realisation views should however be included in concrete system architectures based on the reference architecture description. Thus, this document has sections for these views and provides advice on how to establish these views in actual system architectures derived from the reference architecture description.

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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.

3.1 Overall challenges

The overall challenges to be solved are:

- **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, taking a lot of time and requiring major financial investments in extending capacity. 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. It 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 energy used by the electric vehicles must be as green as possible.** 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 overall functionality provided by the System of interest is illustrated by the reference use cases in Figure 5 (the stakeholder in the diagram are defined in chapter 4). The novel functionality associated to these use cases are described below.

Plan and authorise charging: EV Users get support for more efficient charge planning for predictable access to charge points and charge services. The main innovations in this use case compared to current solutions are:

- A charging request can be initiated by a system acting on behalf of the EV User, e.g. a navigation system. The EV User gets support when the charging request is defined (use of default values, suggestions based on historical data, automated calculation and re-calculation of arrival time to the charge station, etc.)
- Charge point (CP) information on the characteristics of charge points, availability of time slots, prices, etc. for all charge points is used to supports charging decisions.
- A charging request can be issued many hours before the actual charging to reserve a physical charge point as well as the energy to be used. This arranges for predictable access to charge point as well as smart energy management.
- A charging request may also indicate that the EV User will allow V2G.

Charge EV: On arrival to the charge station, the charging can start. The main innovations in this use case compared to current solutions are:

- The EV User will be supported in the identification of a charge point to use. Drop in users can avoid booked charge points, and those who have booked can find the charge point to use.
- The EV User may request and receive information on the status of the charging process
- The EV User may get notification, e.g. when the charging is finalised.

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Manage EV fleet: The main innovation in this use case compared to current solutions is

- The charge planning is integrated in the fleet management. The charging of electric vehicle fleets is planned and managed for optimal utilisation of resources.

Manage charging: The main innovations in this use case compared to current solutions are:

- Charge point information with information on the characteristics of charge points, availability of time slots, prices, etc. is published to support charging planning and decisions.
- Charge booking is supported to provide predictable access to charge points. The booking of charge points is enforced to prevent blocking of charge points.
- V2G is supported and the electric vehicle batteries are offered as an energy storage to the local energy management.
- Detailed descriptions of the energy characteristics are received from the local energy management and arrange for analysis of savings (both money and emissions).

Provide roaming: The main innovations in this use case compared to current solutions are:

- In addition to roaming of booking and payment, the roaming of energy demands and V2G is supported
- Decentralised roaming is supported (interoperability between roaming providers) (Ferwerda, Bayings et al. 2018)

Manage energy use and storage: The main innovations in this use case are

- Hierarchical energy management at different levels of the local grid (e.g. from the whole neighbourhood to subsets of the grid) and collaboration between the levels facilitate flexible energy management structures and strategies.
- Local energy management for smart and green charging as part of the above-mentioned hierarchy facilitating charging with minimal grid investments through peak shaving and optimal use of energy from local renewable energy sources (RES), e.g. PVs. Holistic optimisation of the energy use and storage will facilitate energy flexibility. (Junker, Azar et al. 2018) states that solutions, taking "all" energy demands in the neighbourhood and V2G into account, represent a paradigm shift from traditional supply control to demand control.
- Integration with the local energy management facilitates electric vehicle charging when energy is available. Historical data and data from bookings facilitate better prediction of the power demand over time, and the energy use plan for electric vehicle charging can be optimised.
- Energy surplus will be stored in local energy storages and in the batteries of connected vehicles and used when needed (V2G).
- Savings both regarding economy and emissions are calculated based on information on energy characteristics and energy use.

Plan and execute other energy demanding activities: The main innovation in this use case is.

- The energy demands and schedules for energy demanding activities are executed according to the energy use plan established by local energy management, which is a part of the local energy management described above.

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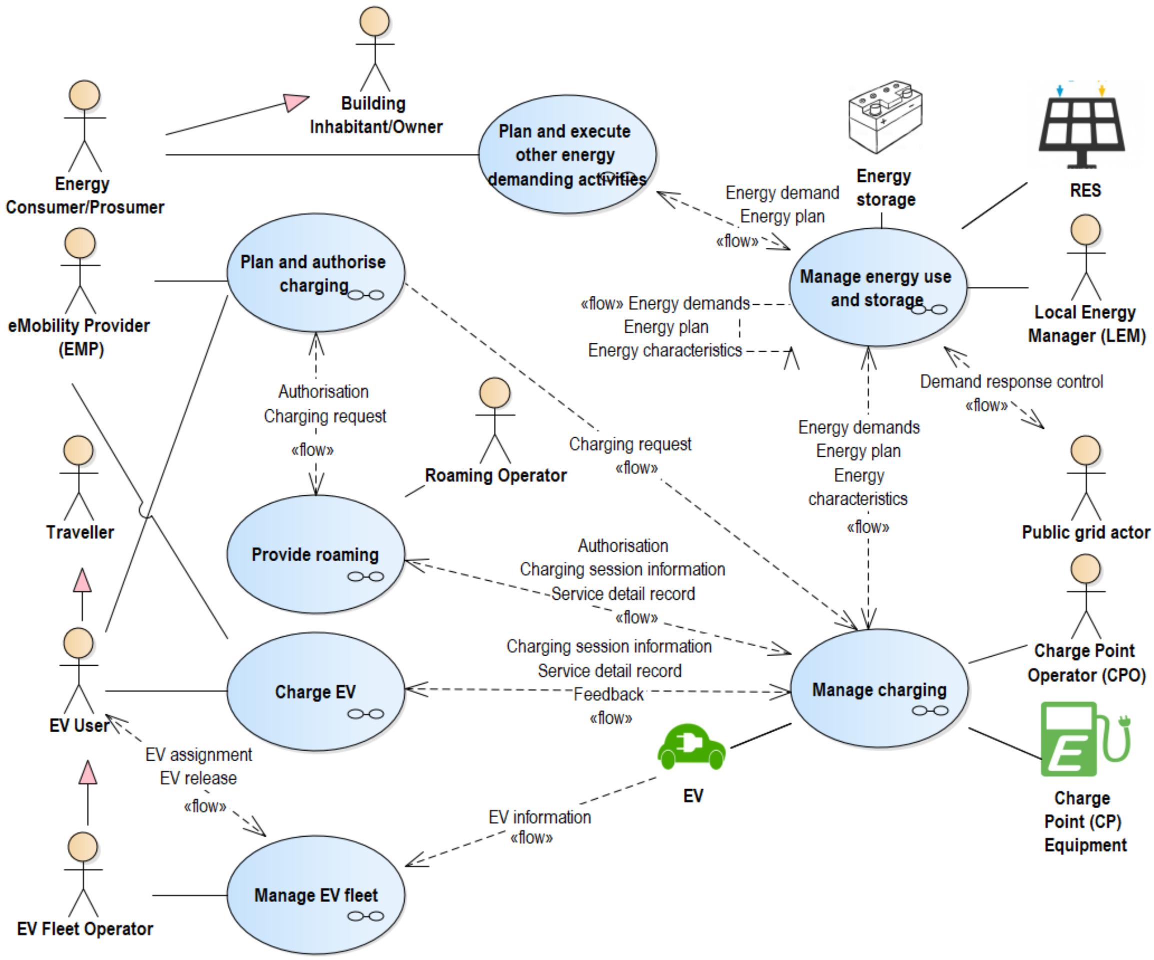

Figure 5 Overall functionality provided by the System of interest

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3.3 Domain concept model

Figure 6 depicts a domain model which 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.
- The *service* stereotype indicate that the concept is a digital service.
- 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.

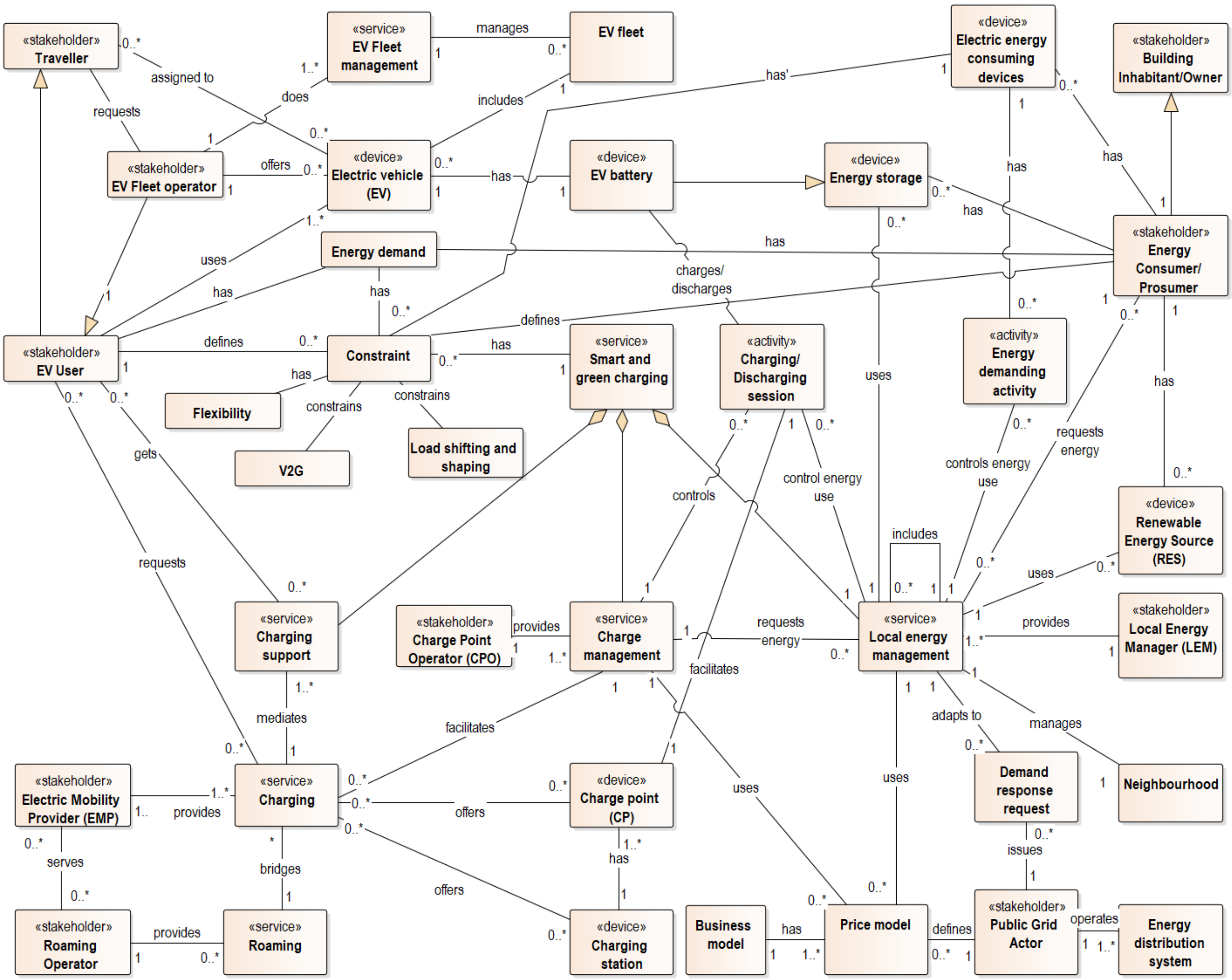

Figure 6 Domain model

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

- EV Users get Charging support when they need to charge their Electric Vehicle (EV), and the Charging support mediates access to Charging. Charging is a service provided by an Electric Mobility Provider (EMP). Charging is requested by EV Users and are offered at Charge stations and by Charge points. One Charge station may have many Charge points.
- Charge management is a service provided by a Charge Point Operator (CPO). The Charge management facilitates Charging, and controls the Charging/Discharging sessions, which are facilitated by a charge point (CP). A Charging/Discharging session charges and/or discharges (in case of V2G) an EV battery.

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- Local energy management is done by the Local Energy Manager (LEM). The local energy management may be hierarchical. At the top level, it manages the energy use in a neighbourhood, and the energy use is adapted to Demand response request issued by Public Grid Actors that operates the Energy distribution system. At lower levels, the Local energy management manages subsets of the local grid.

  Based on energy requests from Energy Consumers/Prosumers (who have Energy consuming devices with Energy demanding activities) and the Charge management, the Local energy management optimises an energy use plan and controls the energy use of Energy demanding activities and Charging/discharging sessions.

  The Local energy management decides how to use energy from local Energy storages and local Renewable Energy Sources (RES) when the energy demand is to be fulfilled. The Local energy management may also choose to use local Energy storages to store energy produced by local Renewable Energy Sources (RES).

- The optimisation is based on the energy demands of the Energy demanding activities, and the ability to use energy from local Energy storages and local Renewable Energy Sources (RES). The Energy storage may be an EV battery (in case of V2G).

The Charge management, the Local energy management uses a Price model of a Business model to do billing. The Public Grid Actors operating the Energy distribution system also defines such price models (tariffs) for use of energy from the energy distribution system.

An EV User uses an Electric Vehicle (EV), and thus, the EV User has an Energy demand. Similarly, an Energy Consumer/Prosumer also has an Energy demand due to his/her Electric energy consuming devices. EV Users and Energy Consumers/Prosumers define constrains related to their Energy demands. The Constraint may have flexibility and may constrain V2G as well as load shifting and shaping of the energy profiles to be provided. As described above the EV User gets Charging support and requests Charging, which contributes to Smart and green charging according to the constraints.

Electric vehicles (EVs) have EV batteries that are charged or discharged by Charging/Discharging sessions. In case of discharging, the EV battery of the Electric Vehicle (EV) is used as an Energy storage.

A Traveller may request services from an EV Fleet Operator. The EV Fleet Operator operates Electric Vehicles (EVs) and does EV fleet management and manages an EV fleet that includes Electric vehicles (EVs). Depending on the services offered by the EV Fleet Operator, Electric Vehicles (EVs) may be offered to Travellers (e.g. in case of shared EVs). In such cases the Traveller becomes and EV User.

When the EV Fleet Operator needs charging of electric vehicles in the EV Fleet, the EV Fleet Operator becomes an EV User.

A Roaming Operator serves the Electric Mobility Provider by providing Roaming services. Such services bridge the Charging provided by different Electric Mobility Providers so that the EV User can use the services regardless of with which EMP he/she has a subscription.

Use of this model as a blueprint in system architecture descriptions: Concepts and terms of relevance should be identified. The model can be extended and refined with concepts/terms of relevance to the actual system.

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4 Stakeholders

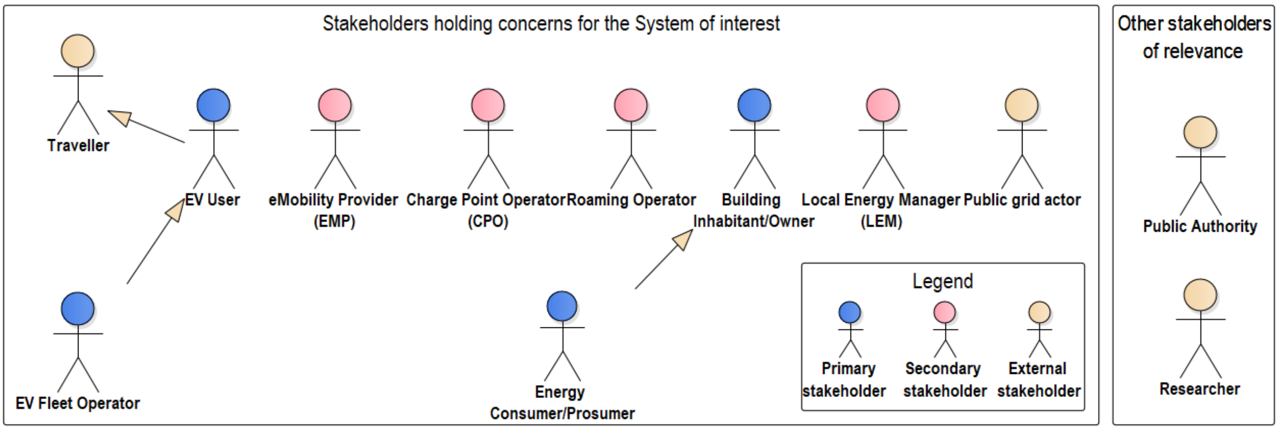

Figure 7 Stakeholders of relevance

The architecture description uses generic stakeholder types to specify the concept and the solution. The stakeholder types of relevance are depicted in Figure 7. Those holding concerns for the System of interest are also in Figure 5, where their relations to the overall functionality (depicted as use cases) are illustrated. In Figure 7, the stakeholders are categorised as:

- *Primary stakeholders* that take the initiatives. These are EV User, EV Fleet Operator, Building Inhabitant/Owner 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 Actors and the Traveller.

4.1 Stakeholders holding concerns for the system of interest

Figure 7 shows the stakeholders holding concerns for the system of interest, and Figure 5 illustrates the related reference use cases. The stakeholder types are described as follows (the definitions are based on the pre-release of IEC 63119-1 (IEC 2019), but extended with issues that are specific to GreenCharge to clarify the role of this stakeholder in relation to the GreenCharge concept):

- The *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).
- The *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.
- The e*Mobility Provider (EMP)* provided 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 may operate a roaming endpoint, meaning that the EMP provides functions that arrange for roaming.

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- The *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 arrange for roaming.
- The *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 EV Users to use a single credential and contract to access charge services provided by multiple EMPs or CPOs through the roaming endpoints.
- The *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.
- The *Building Inhabitant/Owner* has equipment and installations in its apartment or building that requires energy. Building Inhabitants/Owners may also have one or more (private) charge points.
- The *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.
- The *Public Grid Actors* are Distribution Service Operators (DSOs) and retailers. They operate the energy distribution system, define tariffs and may request demand response from the energy management system of the LEM.
- The *Traveller* has a mobility demand that 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.

Note that in this architecture description, the responsibilities and scopes of the different stakeholder types do not overlap. In this way, we can avoid duplicated descriptions for the different stakeholder types. One actor in the real world may however play the role of several stakeholder types. For example:

- 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 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 a Building Inhabitant.

Some stakeholders are not directly addressed by the GreenCharge solution but may still take some of the roles represented by the stakeholder types listed above, for example:

- Parking operators may be EMPs.
- 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.
- MaaS operators may integrate towards EV Fleet Operators and EMPs to integrate transport services provided with different types of electric vehicle fleets and charge services into transport chains. In such cases the MaaS Operator is an EV User.

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4.2 Other stakeholders of relevance

Figure 8 shows other stakeholder types of relevance than those involved or contributing with the GreenCharge solutions. These will affect or be affected by the GreenCharge solution.

- The *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.
- The *Researcher* will use research data automatically collected from the GreenCharge solution running at the pilot sites in simulations and evaluations to generate new knowledge. The knowledge will support the public authority's work on policies and SUMPs.

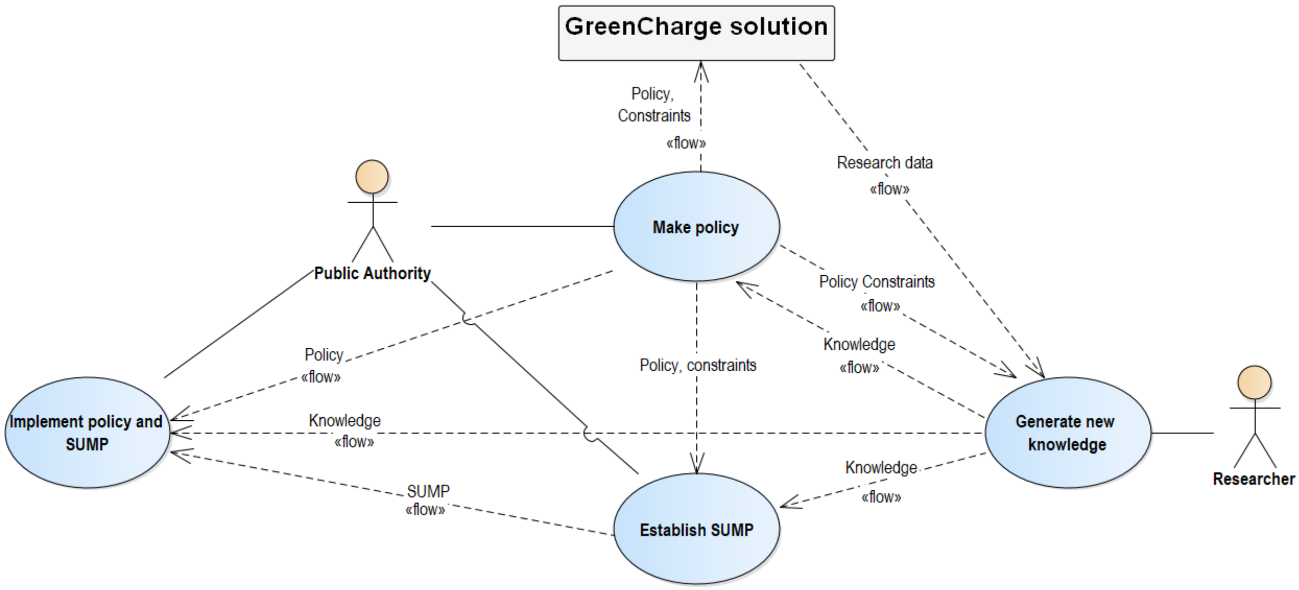

Figure 8 Overall use cases that are not directly addressed by technical solutions

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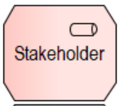
5 Concerns

This chapter analyses the concerns of the stakeholders, and a set of overall goals to be reached to meet the concerns are identified. These goals are in Chapter 7 used to identify the overall requirements.

5.1 Motivation model

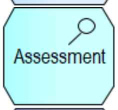
The overall concerns of the stakeholder types addressed in Chapter 4 are analysed through a structured approach guided by Archimate motivation models. The focus is on the need for changes (towards eMobility and sustainable behaviour), and for each stakeholder type the motivations for changes are identified and analysed.

The following model elements are used in the Archimate motivation model:

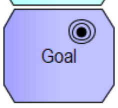


Stakeholder type addressed. See definitions of stakeholder types in Chapter 4.

Driver that motivate 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. A complete list of the goals identified is provided in section 5.2. These goals are the starting point for the overall requirements defined in Chapter 7.

The drivers, assessments and goals of each stakeholder type are described below.

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.

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5.1.1 EV User motivation model

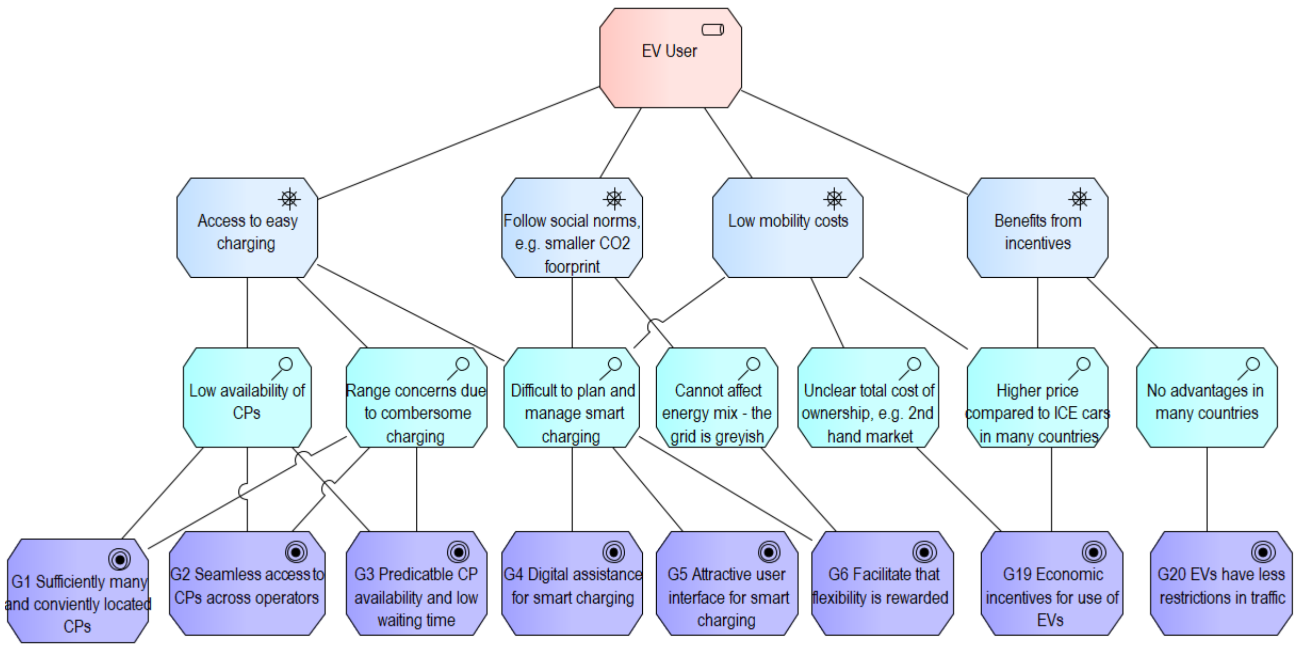

Figure 9 EV User motivation diagram

The drivers and assessments associated to the EV User motivation model are described in Table 3. The goals are described in Table 12 in section 5.2.

Table 3 EV User drivers and assessments

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. • Extra waiting time might be required if the charge point is occupied.
	Difficult for 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

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	• 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 DSO, and currently the mix is not completely green (the CO2 intensity varies between countries).
Low mobility costs The charging costs are reduced	**Difficult for EV User 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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5.1.2 EV Fleet Operator motivation model

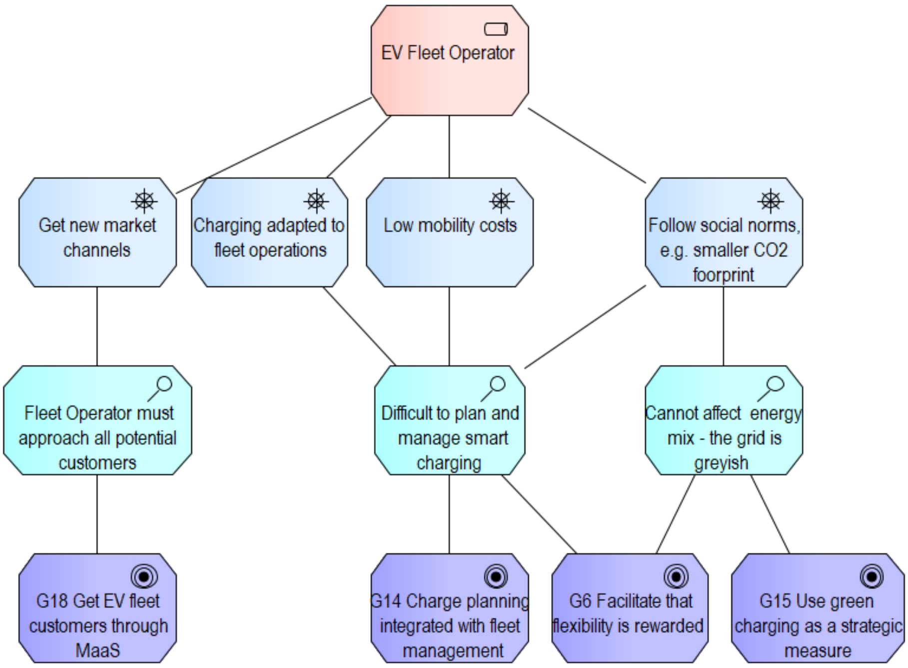

Figure 10 EV Fleet Operator motivation diagram

The drivers and assessments associated to the EV Fleet Operator motivation model are described in Table 4. The goals are described in Table 12 in section 5.2.

Table 4 EV Fleet Operator drivers and assessments

Driver	Assessment of the current situation
Get new market channels EV Fleet Operators need new customers that they cannot reach today.	**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).
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** The planning of fleet operations is complicated due to the charging. Time for charging must be accounted for. – See also description in 5.1.1
Low charging costs With lower charging costs, the profit will increase	**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 DSO, and currently the mix is not completely green (the CO2 intensity varies between countries).

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5.1.3 eMobility Provider (EMP) motivation model

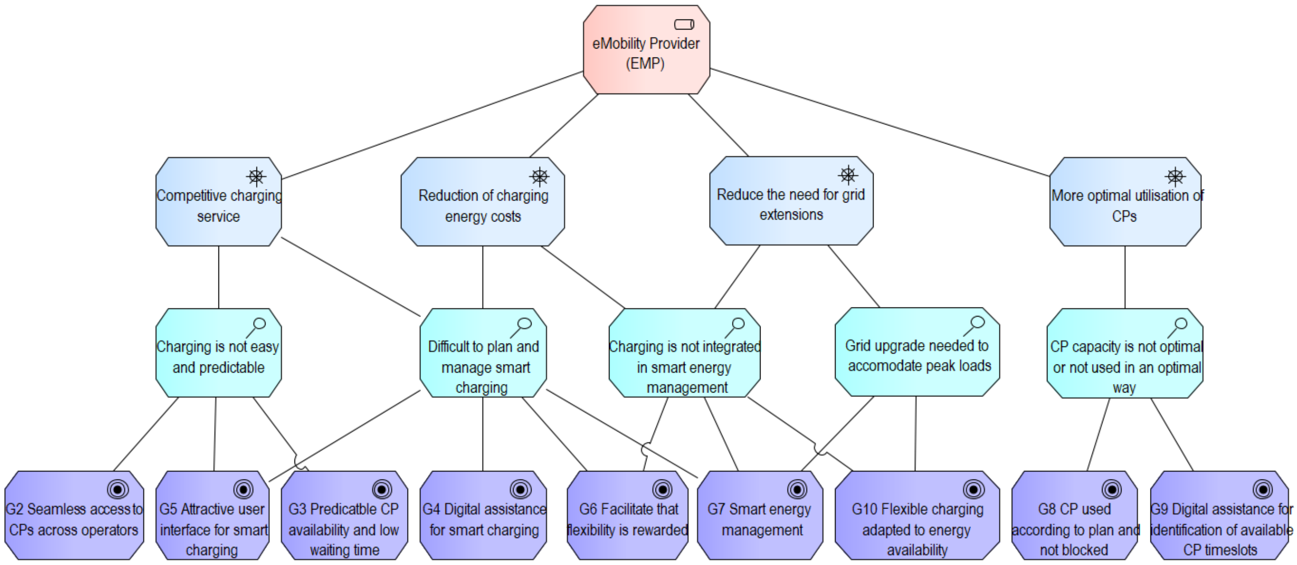

Figure 11 eMobility Provider (EMP) motivation diagram

The drivers and assessments associated to the eMobility Provider (EMP)motivation model are described in Table 5. The goals are described in Table 12 in section 5.2.

Table 5 eMobility Provider (EMP) drivers and assessments

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 5.1.1
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 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

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5.1.4 Charge Point Operator (CPO) motivation model

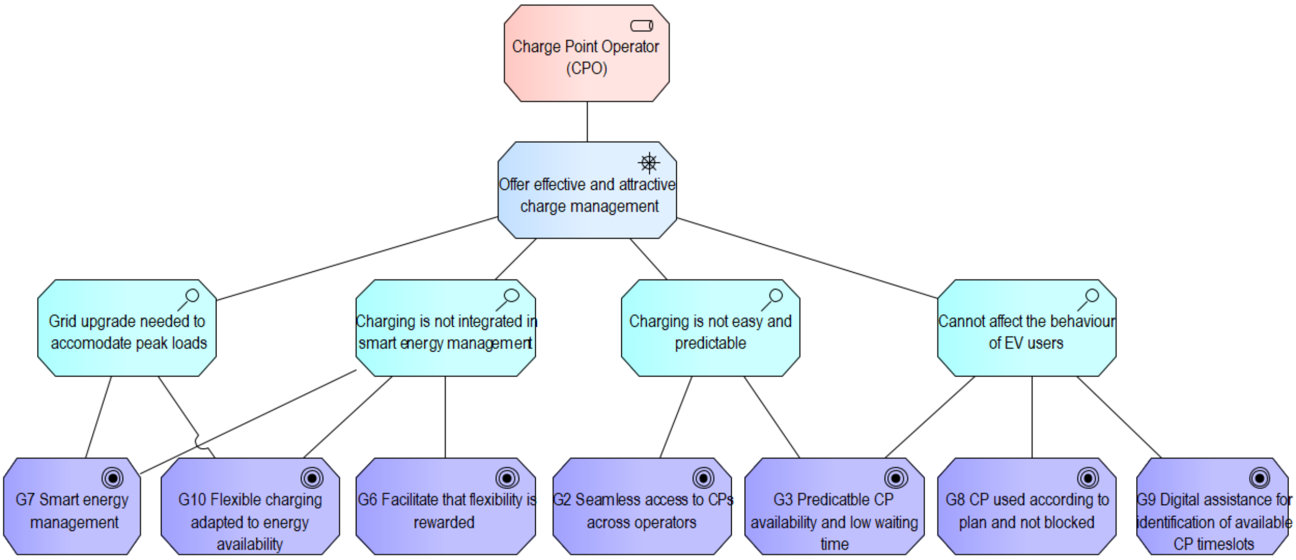

Figure 12 Charge Point Operator (CPO) motivation diagram

The drivers and assessments associated to the Charge Point Operator motivation model are described in Table 6. The goals are described in Table 12 in section 5.2.

Table 6 Charge Point Operator drivers and assessments

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 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.

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5.1.5 Roaming Operator motivation model

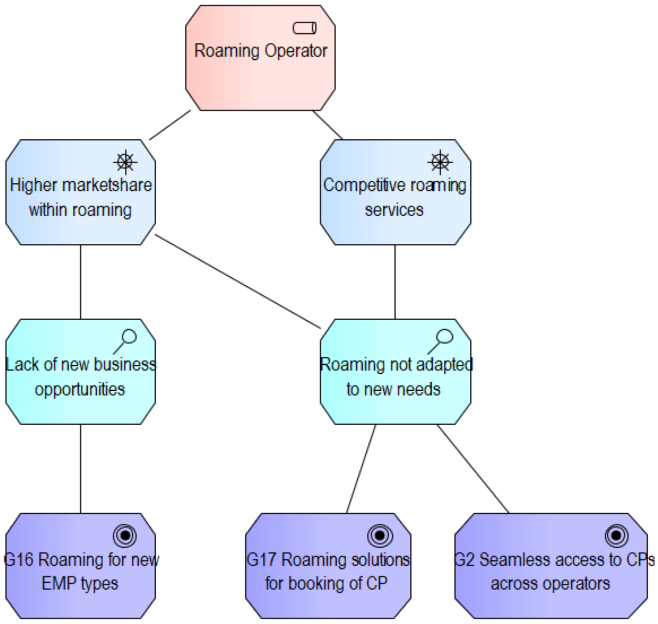

Figure 13 Roaming Operator motivation diagram

The drivers and assessments associated to the Roaming Operator motivation model are described in Table 7. The goals are described in Table 12 in section 5.2.

Table 7 Roaming Operator drivers and assessments

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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5.1.6 Local Energy Manager motivation model

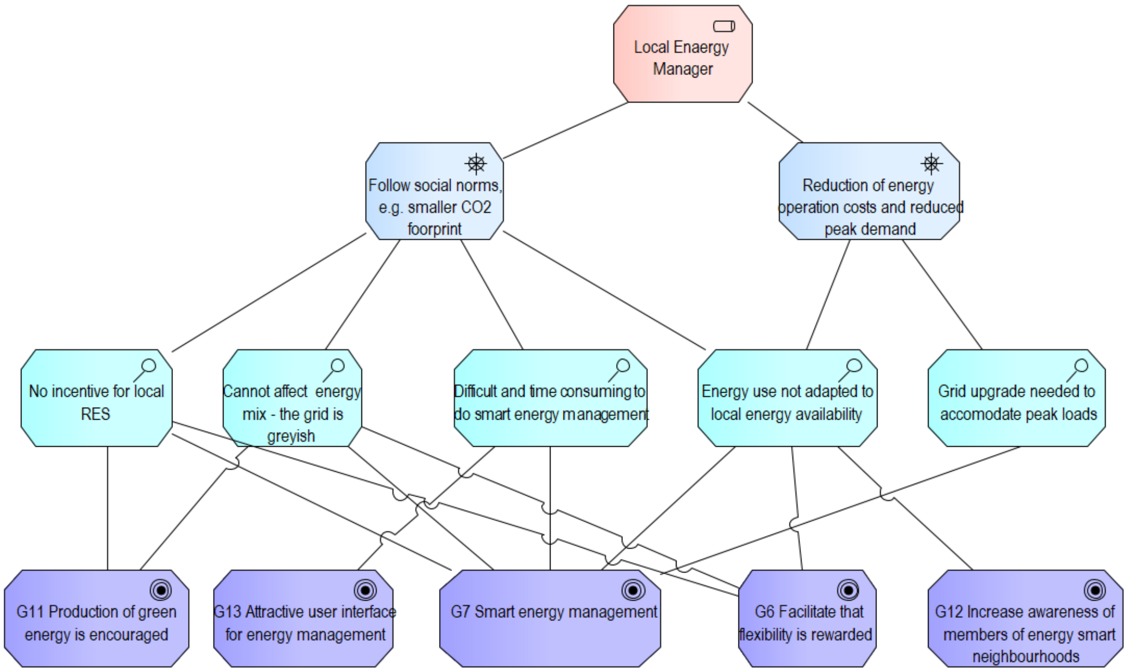

Figure 14 Local Energy Manager (LEM) motivation diagram

The drivers and assessments associated to the Local Energy Manager motivation model are described in Table 8. The goals are described in Table 12 in section 5.2.

Table 8 Local Energy Manager drivers and assessments

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.

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5.1.7 Energy Consumer/Prosumer motivation model

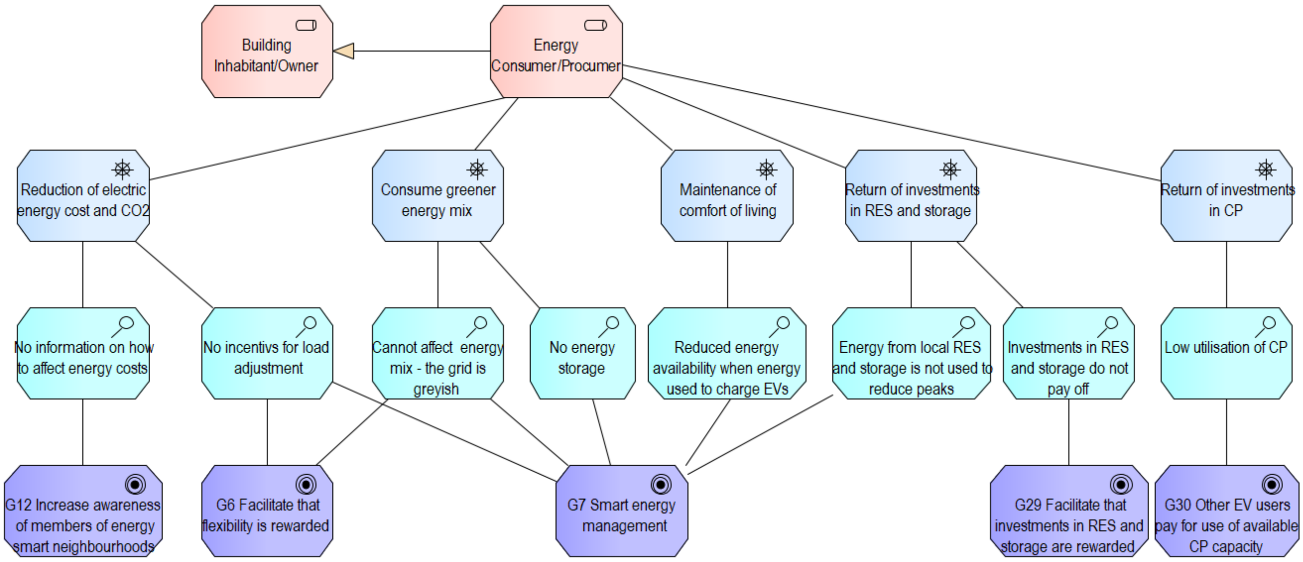

Figure 15 Energy Consumer/Prosumer motivation diagram

The drivers and assessments associated to the Energy Consumer/Prosumer motivation model are described in Table 9. The goals are described in Table 12 in section 5.2.

Table 9 Energy Consumer/Prosumer drivers and assessments

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 5.1.1 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 DSO, 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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5.1.8 Public Authority motivation model

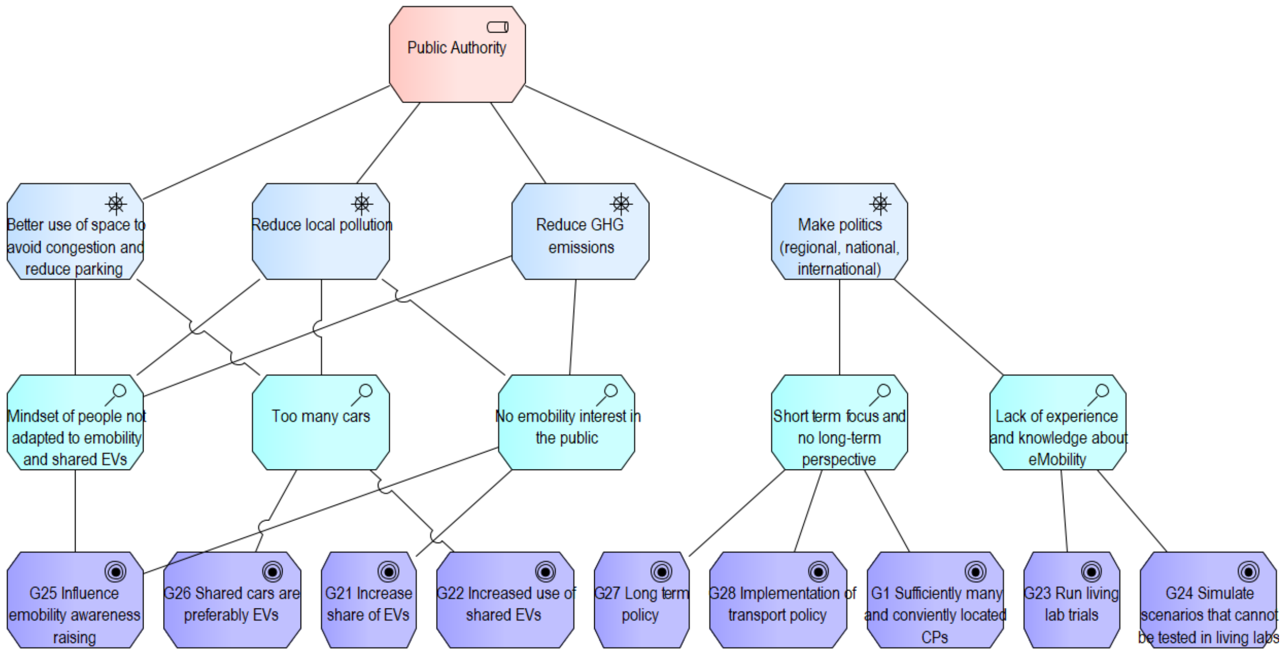

Figure 16 Public Authority motivation diagram

The drivers and assessments associated to the Public Authority motivation model are described in Table 10. The goals are described in Table 12 in section 5.2.

Table 10 Public Authority drivers and assessments

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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5.1.9 Researcher motivation model

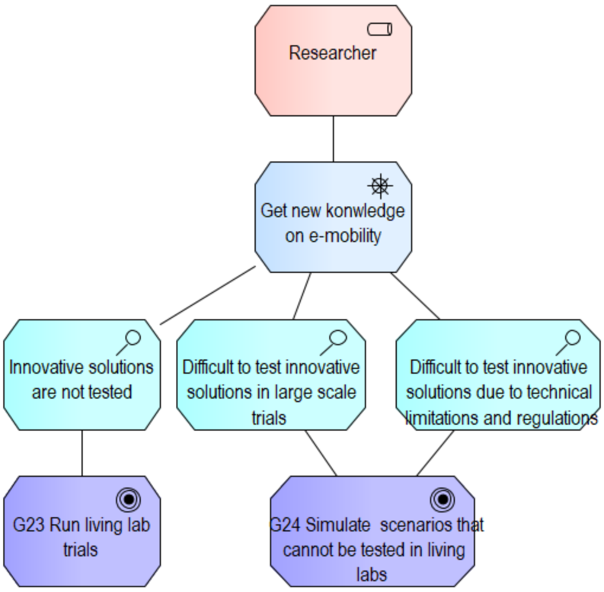

Figure 17 Researcher motivation diagram

The drivers and assessments associated to the Researcher motivation model are described in Table 11. The goals are described in Table 12 in section 5.2.

Table 11 Researcher drivers and assessments

Driver	Assessment of current situation
Get new knowledge on emobility	**Innovative solutions are not tested** Solutions such as those addressed by GreenCharge are not tested and evaluated.
	Difficult to test innovative solutions in large scale trials The solutions owned and managed by different stakeholders are not integrated, data is not available, and the share of electric vehicles are very low in most of Europe.
	Difficult to test innovative solutions due to technical limitations and regulations The integration of different solutions owned and managed by different stakeholders is challenging due to the lack of standards and open interfaces. There are many limitations, e.g.: • electric vehicles do not support V2G • There is no interface for open access to the state of charge of electric vehicles. • In many countries, regulations do not encourage smart energy management and local production of renewable energy • Current business models do not encourage collaboration and optimal solutions

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5.2 Goals identified through the motivation models

The goals derived from the motivation models provided above are listed and described in Table 12. 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)
- Goals related to Research Data (RD)

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 12 Goals to meet derived from the 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
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.	SC EM

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		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.	
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 • Reservation 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
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 CO_2 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	EM

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		• The users must be inspired through feedback information on savings, reduction of CO2 footprint, etc.	
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
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.	RD
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.	RD
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	**Long term policy**	Long term policies for city development and the transport sector must address the transition towards emobility.	PP

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G28	**Implementation of transport policy**	The transport policies must be implemented.	PP
G29	**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
G30	**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 the it is not needed by the charge point owner.	SC

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6 Context view

The context view includes:

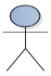
- The use case model. It defines the required functionality and more detailed concerns regarding the solution.
- Use case to service mapping model. It defines the logical services needed and which use cases that are covered by the different services support.
- Environment model. It defines the external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

6.1 Use case model

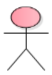
The overall use cases in Chapter 3 are in this section decomposed into more detail reference use cases that cover all the issues addressed by the GreenCharge pilots. The use cases defined by the individual pilots (see the D2.3, D2.9 and D2.16 deliverables) are used as input.

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

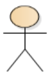
The model elements used in the use case diagrams are:



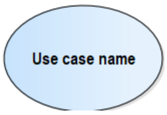
Primary stakeholder taking initiatives.



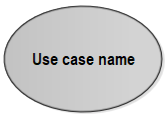
Secondary stakeholder responding to the initiatives of the primary stakeholders.



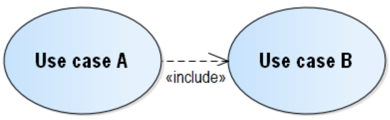
External stakeholder not involved in the GreenCharge solution but contributing to the solution.



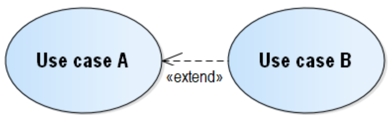
Use case in the depicted use case diagram that is further described by the text below the diagram.



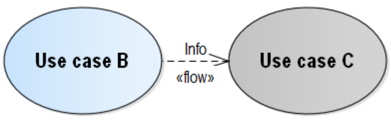
Use case that is outside the scope of the depicted use case diagram. The use case is not described by the text below the diagram. The use case is however decomposed and described in another diagram.



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 5 in Chapter 3.

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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6.1.1 Plan and authorise charging

Today, the EV User decides when and where to charge. In the future the EV User will get decision support, and the charge planning and follow up becomes 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.

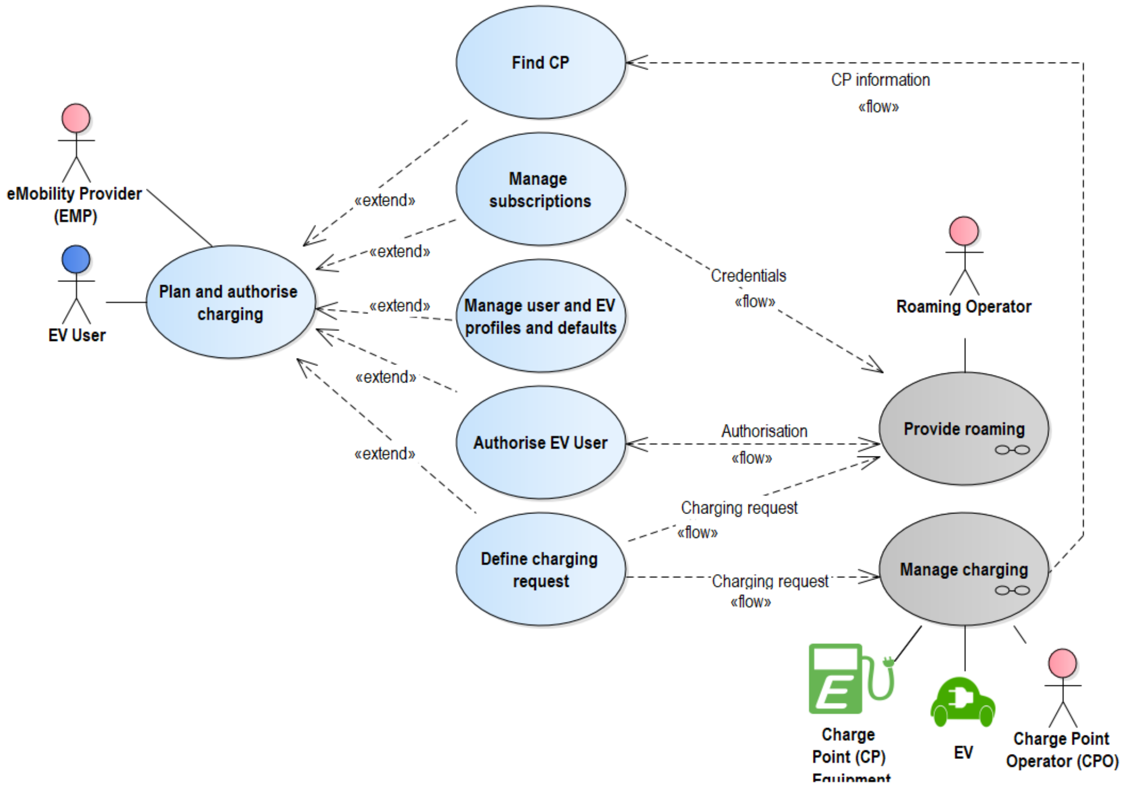

Figure 18 Plan and authorise charging use case

The **Plan and authorise charging** use case is triggered by charging demands and addresses actions that must take place before electric vehicle (EV) charging can start, the definition of the charging request included.

The Alternative Fuel Directive (Directive 2014/94/EU) states that EV Users should be able to charge at any charge point (if available capacity), and eMobility Providers (EMPs) must be able to provide charge services to all EV Users, if there is available capacity.

- EV Users may authenticate via a subscriptions of charge services from an EMP. The EMP may be the "home" EMP or a "guest" EMP.
- Electric vehicles with no subscriptions may authenticate with another payment method (e.g. credit card).
- EV Users may authenticate without the use of a digital services, e.g. using RFID tags at the charge station.

EV Users may use a digital service with a user interface to authenticate and to plan and request charge services (drop in charging, defined timeslot, energy demand flexibility with respect to when the charging must take place, V2G, etc.). The digital service may be offered by the "home" EMP or by third parties. When a third party does not have a business agreement with the "home" EMP, roaming must be used to Authorise EV Users with subscriptions.

When authenticated, the EV User will get a charging session ID that is linked to the charging request.

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

- **Find CP**. This use case is triggered when the EV User needs support to find a charge station. The charge station and the timeslot (in case of booking) that suits the EV User are identified. Information about the charge station locations, characteristics of the charge points, and the availability of charge points, prices, etc. is received from Charge Point Operators (CPOs), and/or third parties, e.g. Roaming Operators and National Contact Points.

- **Manage subscription.** This use case is triggered when an EV User takes the initiative to subscribe to services from an EMP or to update or cancel a subscription. When the EV User has a subscription, the EMP is the "home" EMP. The credentials of the EV Users are registered, and they may also be shared with the Roaming Operator to facilitate roaming of charging requests.

  Service providers (e.g. a Fleet Operator or a MaaS provider) may also have a subscription and thus become EV Users. The customers of these service providers may inherit the credentials of these service providers.

- **Manage customer profiles and defaults.** This use case is triggered when an EV User takes the initiative to register or update the EV User profile with 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, e.g. flags indicating whether flexible charging and V2G are allowed (yes or no), flags indicating the feedback wanted on the charging process (e.g. notifications when charging is finished), priority setting, minimum charging level, the time period for charging, etc.
- **Authorise EV User.** This use case is triggered when the EV User has selected the charge station to use and takes the initiative to request charging, either via a digital service (at any time - long time before or just before the charging) or through other mechanisms at the charge station. It will be verified that the EV User is authorised to charge at the selected charge point. This is done through
  - Authentication of the EV User by means of a subscription or other payment methods (e.g. a credit or a debit card). In case of a subscription, the authentication can be done in several ways
    - By the "home" EMP of the EV User.
    - Through a Roaming Operator. The credentials of the EV User and the identifier of the selected charge point are sent to the Roaming Operator. The Roaming Operator will identify the "home" EMP (based on available information) of the EV User and facilitate an authentication.
  - Verification of that the EV User has the permission to access the charge point.
    - If the charge point is operated by the CPO of the "home" EMP, the access is no problem.
    - If the charge point is operated by another CPO, the Roaming Operator will also verify that the EV User can access the charge point. This means that the CPO supports the roaming.

  If the authorisation is successfully done, a session ID is issued, and the session ID will be used when the charging is requested and will be used in all communication with the CPO regarding the charging request.

- **Define charging request**. This use case is triggered when the EV User is authorised (see above) and acts to express, update or cancel a charging request. The charging request may include a booking of a charge point and/or energy, an energy demand flexibility offering, and a V2G flexibility offering. Default values should be used to reduce the workload. The request will define:
  - The session ID confirming the authentication of the EV User
  - Priority (optional). High priority bookings may cause cancellations of other bookings.
  - Time period in which the charging should take place (earliest start and latest finish)
  - Minimum charging level (to be charged as soon as possible)
  - State of Charge (SoC) when the electric vehicle is connected
  - The SoC to be reached
  - Minimum charging level when V2G
  - Notification requests
  - Flag indication flexible charging or not (charging at any time within the time period provided)
  - Flag indicating that V2G is allowed

  The charging request is sent to the CPO or 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.

6.1.2 Charge EV

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

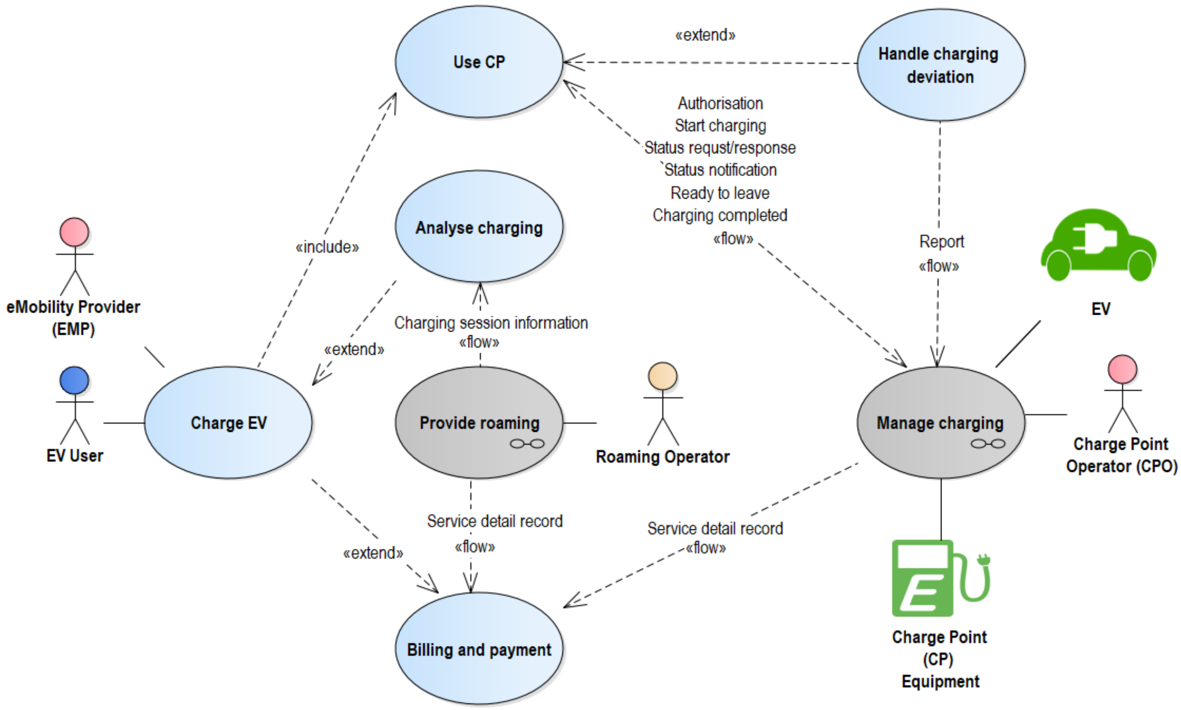

Figure 19 Charge EV use case

The **Charge EV** use case is triggered by the arrival to the charge station. Depending on the situation, the use case will:

- **Use CP.** This use case is triggered by events related to the actual charging. It handles the information exchange between the Charge Point Operators (CPO) and the EV User related to upcoming and ongoing charging sessions.
    - The EV User is notified according to the user preferences. The EV User may for example get notifications some time before the start of a booked charging and when the charging is completed.
    - On arrival to the charge station, the EV User is supported in the selection of the charge point to use:
        - The user interface on the charging equipment (displays and signalling) will indicate whether a charge point is booked, available, out of order, etc. If no booking is done, the EV User must select a charge point that is available. When the EV User is authorised (see the overall Plan and authorise charging use case in Figure 5 in Chapter 3), the charging can start.
        - When a charge point is booked (in such cases the EV User is already authenticated), the CPO will provide information to the EV User via a digital service on which charge point to use.
    - At the start of the charging, the EV User sends a start charging message to the CPO. Provided that the EV User is authorised to use the charge point (see the Plan and authorise charging use case), the electric vehicle (EV) can be connected to the charge point.
    - During charging, the EV User may send status requests and receive status responses.
    - During charging, the EV User may receive status notifications, e.g. in case of deviations.
    - When ready to leave, the EV User sends a ready to leave message to the CPO.

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

- **Handle charging deviation.** This use case is triggered by deviations (e.g. if the electric vehicle cannot be charged according to the charging request). The EV User is notified about the deviation and must decide how to cope with the situation. If the EV User wants to report a fault, this use case supports the reporting.
- **Analyse charging.** This use case will record the detailed service records received from the CPO or from a Roaming Operator (if the charge points operated by a CPO with no business relation with the EMP) and provide analysis and statistics on charging sessions. The EV User will get overviews analysis and statistics, e.g. the savings (both 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 and payment.** This use case is triggered when billing and payment is needed. The EMP will do billing and request payment based on a service detail record received from the CPO or from a Roaming Operator (if charge points operated by a CPO with no business relation with the EMP).

6.1.3 Manage EV fleet

The charging of the electric vehicles (EVs) must be an integrated part of the fleet management. The charging must be adapted to the upcoming fleet operations.

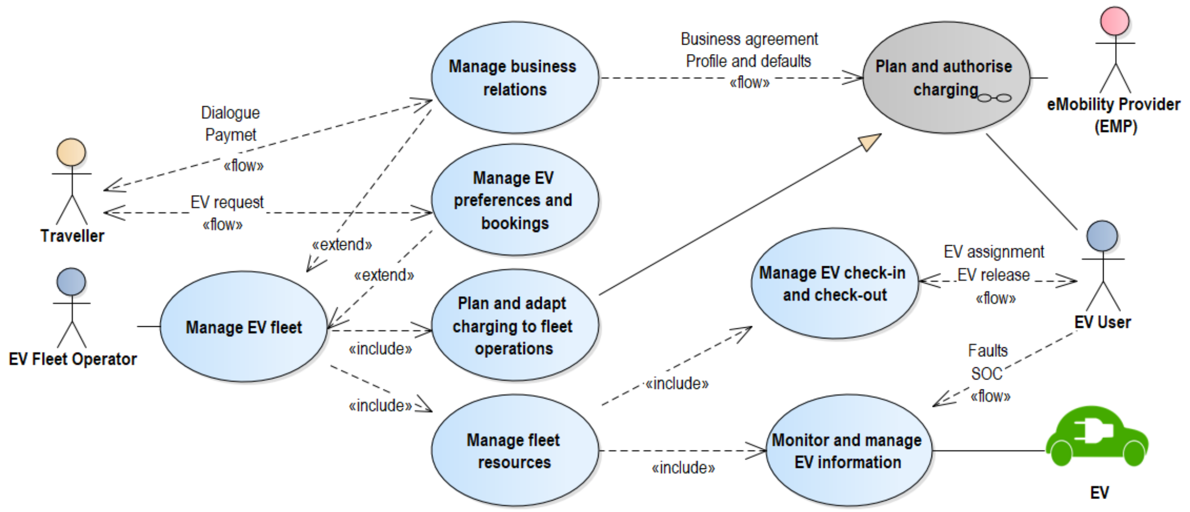

Figure 20 Manage EV Fleet use case

Depending on the situation, the **Manage EV Fleet** use case will be extended by these use cases:

- **Manage business relations.** This use case is triggered when an EV Fleet Operator establishes, updates or cancels business agreements. This may be business agreements with
  - Travellers. In such cases the use case must
    - Manage information about the users, including information on advantages gained (e.g. extra time), misuse and pending fines included.
    - Manage dialogues with user on problems and questions regarding the use of the electric vehicles
    - Provide information on the business rules (incentives, etc.)
  - Service providers offering use of the EV Fleet to for example travellers, e.g. MaaS providers
  - Service providers providing services to the EV Fleet Operator or those using the electric vehicles, e.g. charge service providers (eMobility Providers (EMPs)).

  This use case will offer information to the EV Users on prices, the benefits achieved using smart and green charging included.

  This use case will manage billing and payment when electric vehicles are used. Depending on the use of the electric vehicle 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.

- **Manage EV preferences and bookings.** This use case is triggered when a Traveller or service provider takes the initiative to book an electric vehicle. The use case supports
  - The specification of the electric vehicle preferences
  - This definition of the expected use of the electric vehicle (duration, check-in location, etc.).
  - 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 payed.)
  - 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.

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  - Updates and cancellations of bookings
- **Plan and adapt charging to fleet operations.** This use case assists the 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. Due to this, the use case is a specialisation of the "Plan and authorise charging" use case where charging requests are adapted to the fleet operations before sent to the Charge Point Operators (CPO) (see Figure 5 in Chapter 3). 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.** This use case manages all the electric vehicles in the fleet. The electric vehicles are maintained and services that supports the operation of the electric vehicles are provided (e.g. battery swapping for light electric vehicles (LEVs)) and services that monitors and supports the use of the electric vehicles.
  - **Manage EV check-out and check-in.** This EV User will authenticate before electric vehicle check-out and register the check-in of the electric vehicle. Depending on the check-in location (at charge station or not), the user may get a reward or a fine. If wanted, the EV User may be allowed to use the subscription of the E Fleet Operator when charging.
  - **Monitor and manage EV information.** The electric vehicle will be monitored through reception of tracking information, State of Charge (SoC) information, etc. and Handle charging deviation from the user.

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6.1.4 Manage charging

Enhanced charge planning assistance and booking of charging is facilitated, as well as charge management with better prediction of the power demand and support for flexibility electric vehicle charging (i.e. charging when energy is available). Information about the energy flexibility (Junker, Azar et al. 2018) can guide the pricing.

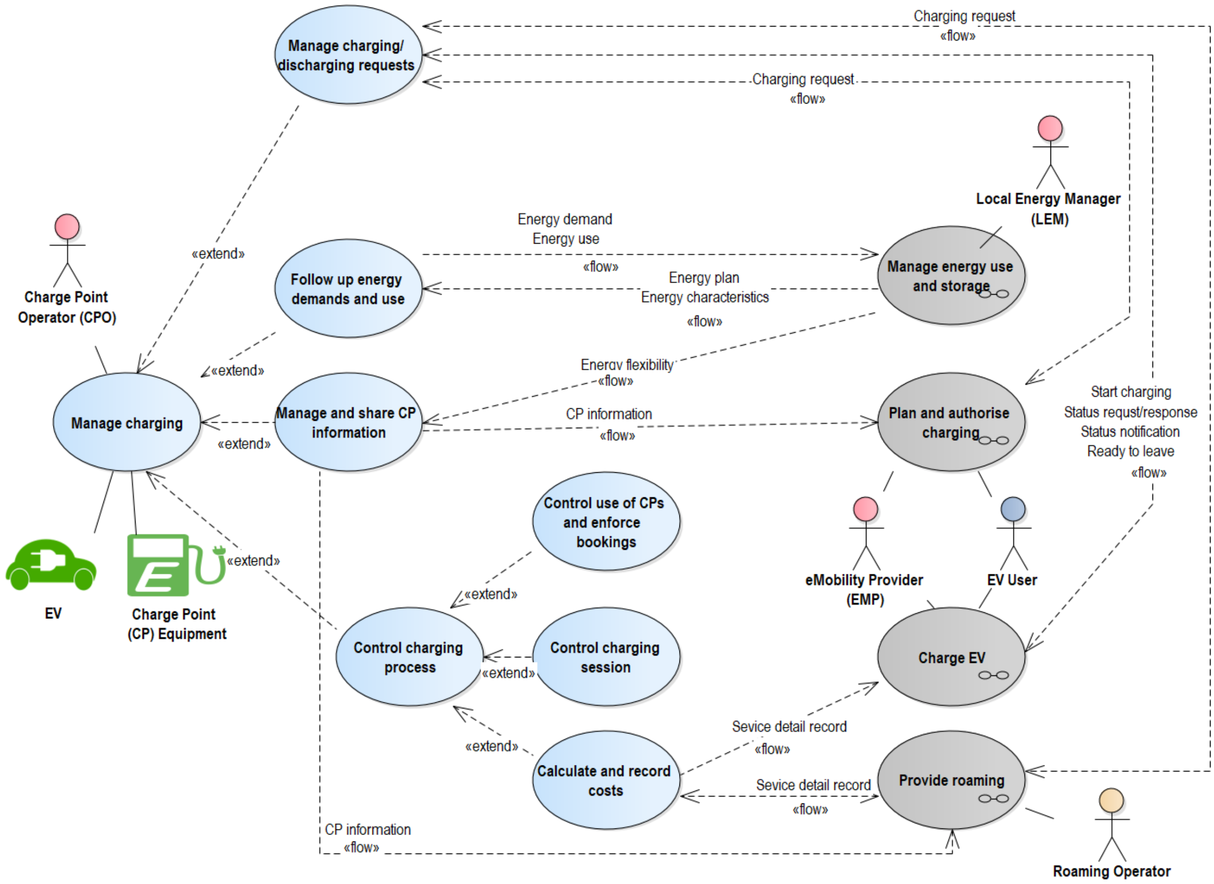

Figure 21 Manage charging use case

The **Manage charging** use case is the CPO's management of the smart charging (adapted to the energy availability) and the operation of the charging infrastructure. Depending on the situation, the use case will:

- **Manage charging/discharging requests.** This use case is triggered by new, updated and cancelled charging request from the EV User (this might also be systems representing the EV User). EV Users may send charging requests at any time, e.g. a long time before the arrival of the electric vehicle (e.g. in case of bookings) or when electric vehicles are at the charge point. The charging request will confirm that the EV User is authorised.

  This use case will also follow up the charging/discharging request and handle the information exchange with the EV User.
  - A start of charging message from the EV User indicating that the charging starts.
  - The user may for example be notified some time before the booked charging session can start.
  - EV Users that have booked a charge point will get a status notification that identifies the charge point to use.
  - During charging, status requests from the EV User is received and status responses are provided.
  - During charging, status notifications are sent to the EV User, e.g. in case of deviations.
  - A ready to leave message is received when the EV User is ready to leave.

A *detailed service record* is generated and managed for finalised charging sessions based on the charging session information and the energy characteristics received from the Local Energy Manager (LEM) (see the Manage data for statistics use case below). 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.
- Details about the energy used – to facilitate statistics, analysis and assessments of gains related to smart charging (based on data received from Local Energy Manager (LEM) – see below)
  - 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

- **Follow up energy demands and use.** This use case sends energy demands to the Local Energy Manager (LEM) based on received charging requests and manages the energy use plans for optimal use of energy received in return.

  This use case also receives 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

  The use case reports information about the actual energy use for each charging session to the Local Energy Manager (LEM).

- **Manage and share CP information.** This use case is triggered by issues that affects the statuses of the charge points and prices for charging. The following information is managed:
  - 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.).
  - The prices for charging. The prices for a period may for example be decided based on
    - The energy flexibility offered by the Local Energy Manager (LEM)
    - Historical data on charging demands.
    - The price policy. Price reductions may 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,

  The information is published via National Contact Points (NCPs) or other channels (the European Regulation EU Reg 2017/1926 requires that parts of the information listed above is shared)

  This use case will also provide information via the charging equipment's user interface (display) on the availability of the charge point and its operative status.

- **Control charging process.** Depending on the situation, this use case will
  - **Control use of CPs and enforce bookings**. This use case will assign charge points to EV Users that have booked charge points and provide information on which charge point to use.

    This use case will also and communicate the availability of charge points through the user interfaces of the charging equipment (display or signalling) to avoid that booked charge points are used by EV Users that are not authorised to use them.

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.

Before an electric vehicle can get charges at a charge points, this use case will

- Verify that the EV User is authorised to use the charge point.
- Detect if the booked charge point is misused by other EV Users (EV User authorisation's session ID must correspond to the session ID assigned to the EV User with the booking).

The use case will also detect electric vehicles that are blocking charge points after the booked timeslot. In such cases

- The EV User is will get feedback on the deviation.
- An extra fee may be added (see Calculate and record costs below).

- **Control charging process.** This use case controls the charging equipment and the. charging/discharging of electric vehicles.

  The operative status of the charging equipment is managed, and the display/signalling of the charging equipment is controlled to

  - Signal the availability of the charge point.
  - Provide information on malfunctions and deviations.

  When an electric vehicle is connected, charging/discharging is started, stopped and controlled according to the individual plan for the charge point, provided that the EV User is authorised. The charging/discharging process is monitored, and the charging session information is registered (to be used when the detailed service record is established). The charging/discharging may be carried out in many charging sub-session. 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.** When a charging session is completed, this use case will provide a service detail record that includes all the information needed for billing and payment to the EMP. 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.) will be calculated according to pre-defined rules.

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.

6.1.5 Manage energy use and storage

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

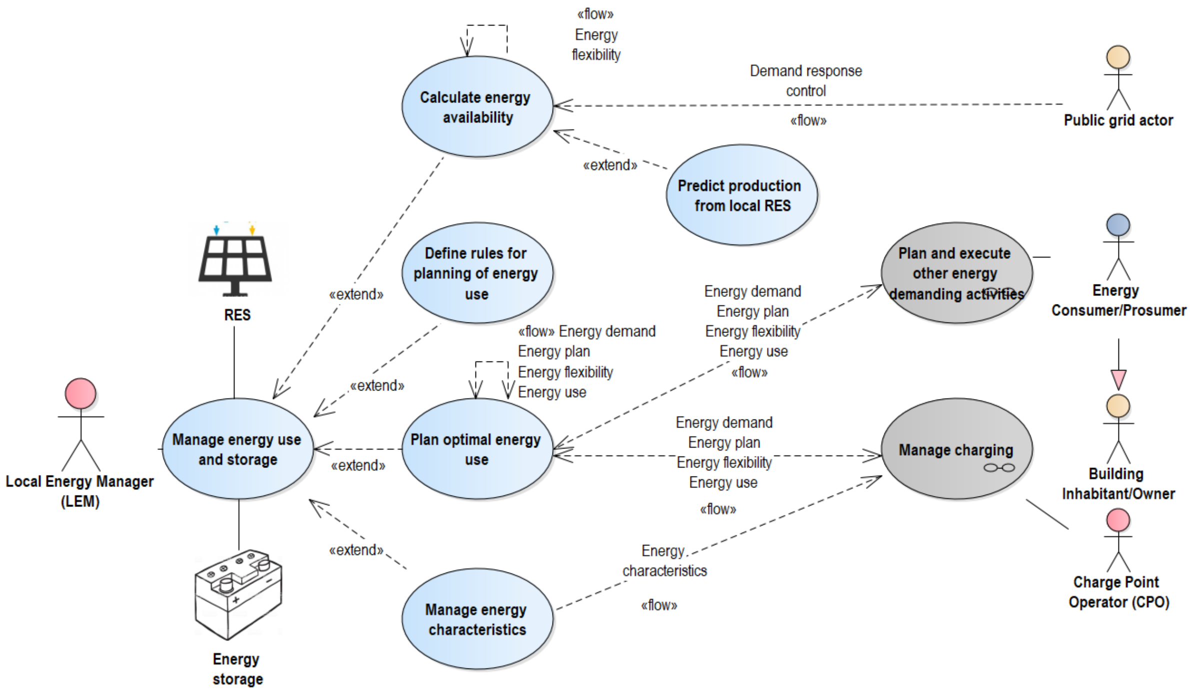

Figure 22 Manage energy use and storage use case

The **Manage energy use and storage** use case addresses smart energy management in a local energy community. This may be a building, a neighbourhood or an area. Depending on the situation, the use case will:

- **Calculate energy availability.** This use case is triggered by issues that may change the energy availability. The use case will maintain an overview of:
  - Demand response input from the DSO
  - V2G flexibility offerings (based on the indication of V2G flexibility in the energy demands form the CPO).
  - Energy in local storage
  - In case of a hierarchical local energy management solution: Energy flexibility from linked local energy management systems, e.g. in case of surplus production from RES in the linked local energy management systems.

  If local RES is available, the use case will also consider the energy availability from these sources
  - **Predict production from local RES.** When local RES is available, this use case provides an overview of future energy availability from local RES. The production is predicted based on input on the weather forecast.

  The use case will, based on the above, calculate and maintain an overview of future energy availability. If energy surplus, energy flexibility may be offered to linked local energy management systems.
- **Define rules for planning of energy use.** This use case is triggered by the need for definition of update of rules for the planning of the energy use. The rules (priorities, rules for handling of energy shortage, rules

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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.** 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 is triggered when the energy availability is changed (detected by the Calculate energy availability use case) and/or the energy demand is changed. The use case will use the rules for energy use, information about the energy availability (established above) and input on energy demands from energy demanding activities (charging sessions included) to *make an optimal plan for the use of available energy*. 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 not enough.
    - What to do with energy from RES (self-consumption, storage in stationary batteries, or selling)
    - The use of energy by the energy demanding activities to be managed, charging sessions included, according to defined rules (e.g. priorities).

  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 as energy flexibility 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 flexibility 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.** Adapted to the sampling periods decided, this use case will
    - Use reports on energy use over time to log the actual energy use for among others charging
    - Log the actual energy production from local RES over time
    - 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.).
    - Calculate the costs/gains related to the actual energy use/production and provide information energy users and prosumers.

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6.1.6 Provide roaming

I addition to roaming of booking and payment, the roaming of energy demands and V2G is also supported, as well as interoperability between Roaming Operators (Ferwerda, Bayings et al. 2018).

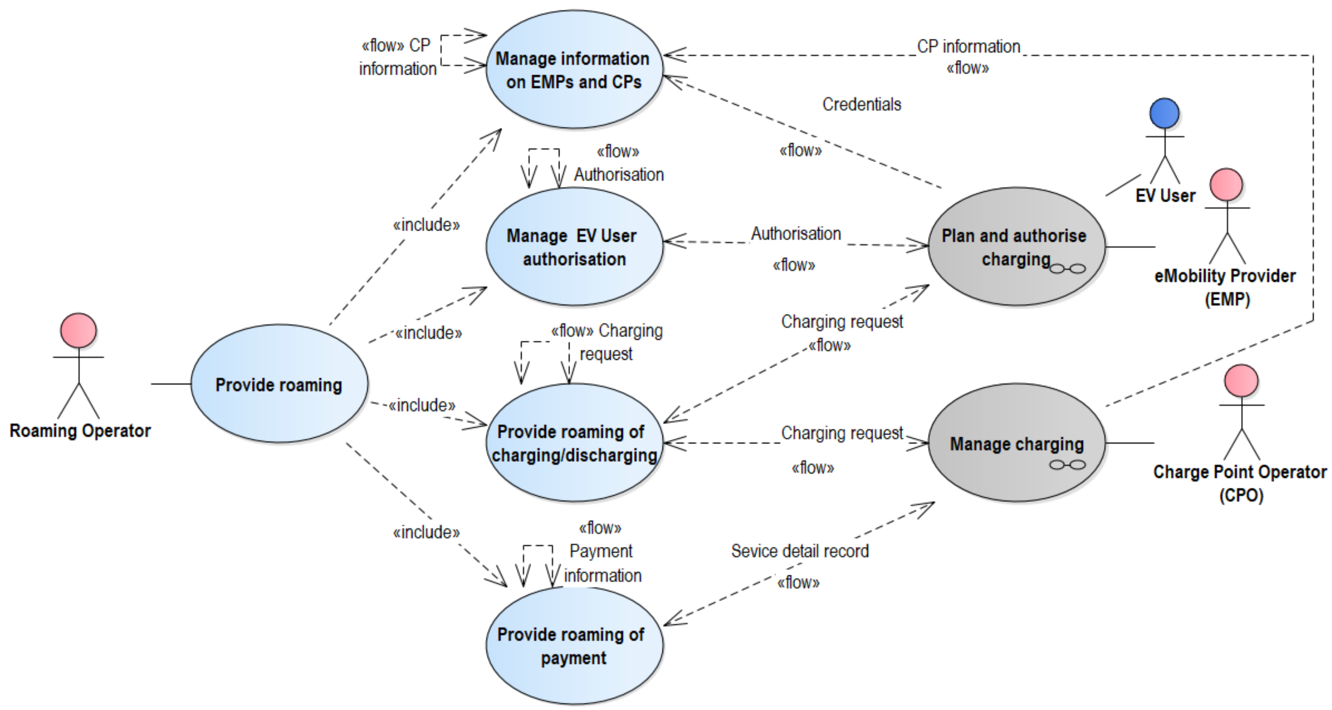

Figure 23 Provide roaming use case

This **Provide roaming** use case performs roaming, i.e. information exchanges and related provisions between eMobility Providers (EMPs), to allow EV Users to use a single credential and contract to access charge services provided by multiple EMPs or Charge Point Operators (CPOs) through roaming endpoints[2]. The need for roaming will depend on

- How the charging request is initiated. Whether it is defined via a digital service provided by the "home" EMP or another EMP/third party or directly defined through the user interface of the charge point.
- The CPO of the selected charge point. Whether the charge point is operated by the CPO of the "home" EMP or another CPO.

The table below indicates when roaming is needed.

Charging request through a digital service provided by		Charging request through CP interface	CP operated by		Roaming needed with respect to		
Home EMP	Guest EMP/ Third party		Home CPO	Guest CPO	Authentication and CP access	Charging request	Payment
x			x		No	No	No
x				x	Yes (for verification of CP access)	Yes	Yes
		x	x		No	No	No
		x		x	Yes	Yes	Yes
	x			x	Yes	Yes	Yes

[2] IEC 63119 pre-release version, 2019

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Depending on the situation, the use case will:

- **Manage information on EMPs and CPs.** This use case will use information received from Charge Point Operators (CPOs) and eMobility Providers (EMPs) to maintain an overview of unique IDs for identification of
    - EV Users and their "home" EMPs
    - EMPs and their Roaming Operators
    - EMPs and their CPOs
    - CPOs and their charge stations and service
    - The characteristics of charge points and service
- **Manage EV User authorisation.** This use case will handle the roaming of EV User authorisation and verify that the EV User can access the charge point. This roaming can be initiated when
    - The EV User uses a digital service provided by a "guest" EMP or a third party with no agreement with the "home" EMP, and the EV User will like the "home" EMP to do the billing. (The EV User does not want to subscribe to a service from the "guest" EMP/third party.)
    - A user interface provided at the charge point when the charge point is operated by a "guest" CPO/EMP
    - A Roaming Operator with no business agreement with the "home" EMP

  The use case will:

    - Use the EV User credentials received (as a part of the authorisation request) to identify the "home" EMP.
    - Do the authentication of the EV User. The Roaming Operator may do this based on information received from the eMobility Providers (EMPs), or the EV User credentials may forwarded to the "home" EMPs for authentication.
    - Identify the CPO operating the charge point.
    - Ensure that the CPO supports roaming and thus will give the EV User access to the charge point.

  The authorisation outcome is reported back to the party that initiated the roaming.

  If the Roaming Operator does not know the EV User or the charge point, the authorisation request may be forwarded to other Roaming Operators.

- **Provide roaming of charging requests.** This use case will handle the roaming of charging requests. The requests are received from
    - Home "EMP" regarding charging at a "guest" CPO
    - Guest eMobility Providers (EMPs) or third parties with no agreements with the "home" EMP
    - A user interface provided at the charge point when the charge point is operated by a "guest" CPO/EMP
    - Other Roaming Operators

  On reception of a charging request, the Roaming Operator sends the request to the CPO operating the actual charge point or to the Roaming Operator representing this CPO (if the current Roaming Operator does not have a business agreement with the CPO).

- **Provide roaming of payment.** This use case will handle the roaming of payment information. A detailed service record is received from
    - The CPO of the "guest" EMP
    - Other Roaming Operators.

  On reception of the detailed service record, the Roaming Operator sends the record to the "home" CPO or to the Roaming Operator representing this CPO (if the current Roaming Operator does not have a business agreement with the "home" CPO).

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6.1.7 Plan and execute energy demanding activities

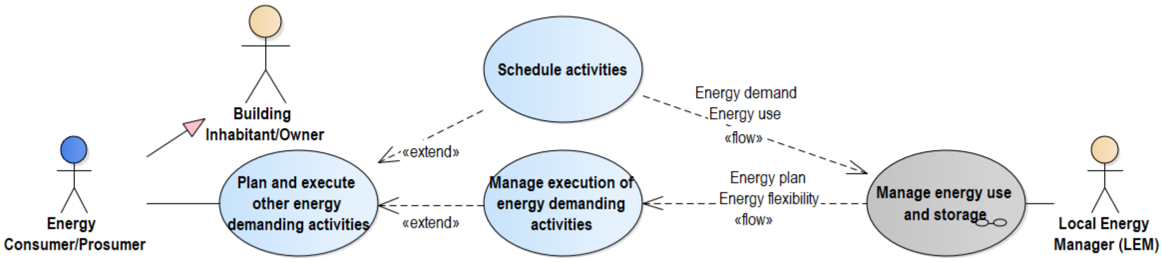

Figure 24 Plan and execute other energy demanding activities use case

The **Plan and execute other energy demanding activities** use case will

- **Schedule activities** that will require energy. This scheduling may also include flexibility with respect to when the activities are to be accomplished. The resulting energy demand (with flexibility included) is provided to the Local Energy Manager.
- **Manage execution of energy demanding activities**. The activities will start and stop according to the plan provided by the Local Energy Manager.

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6.2 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. The services implement the GreenCharge solution described by the use cases depicted in Figure 5. In Figure 25 the boxes represent the services needed to realise the solution.

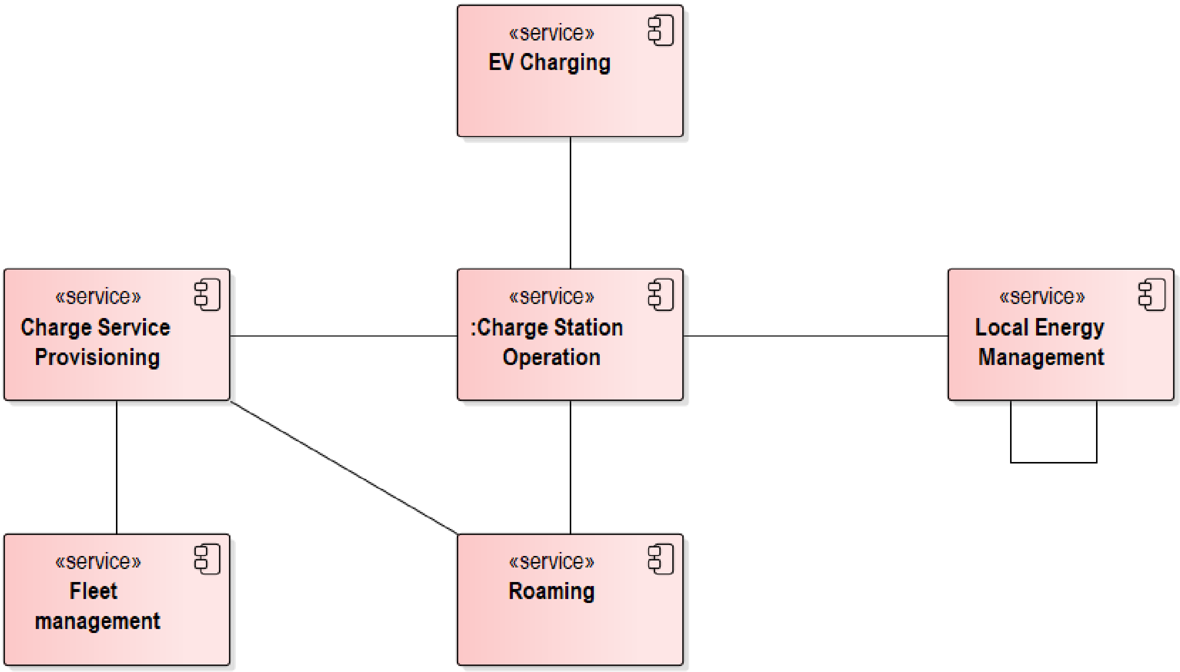

Figure 25 Services in the GreenCharge solution

The services are:

- *Charge service provisioning:* The 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 EV fleets that needs charging.
- *Charge station 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 the energy availability and to other energy demands. This service may collaborate with other similar services in a hierarchy of local energy Management services.
- *EV charging*: The EV User is supported when the charging starts and during the charging (provision of status information, etc.), and billing and payment is handled.
- *Roaming*: Roaming Operators (ROs) provide roaming services.

Figure 26 illustrates the mapping between the overall use cases in section 6.1 and the services in Figure 26.

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

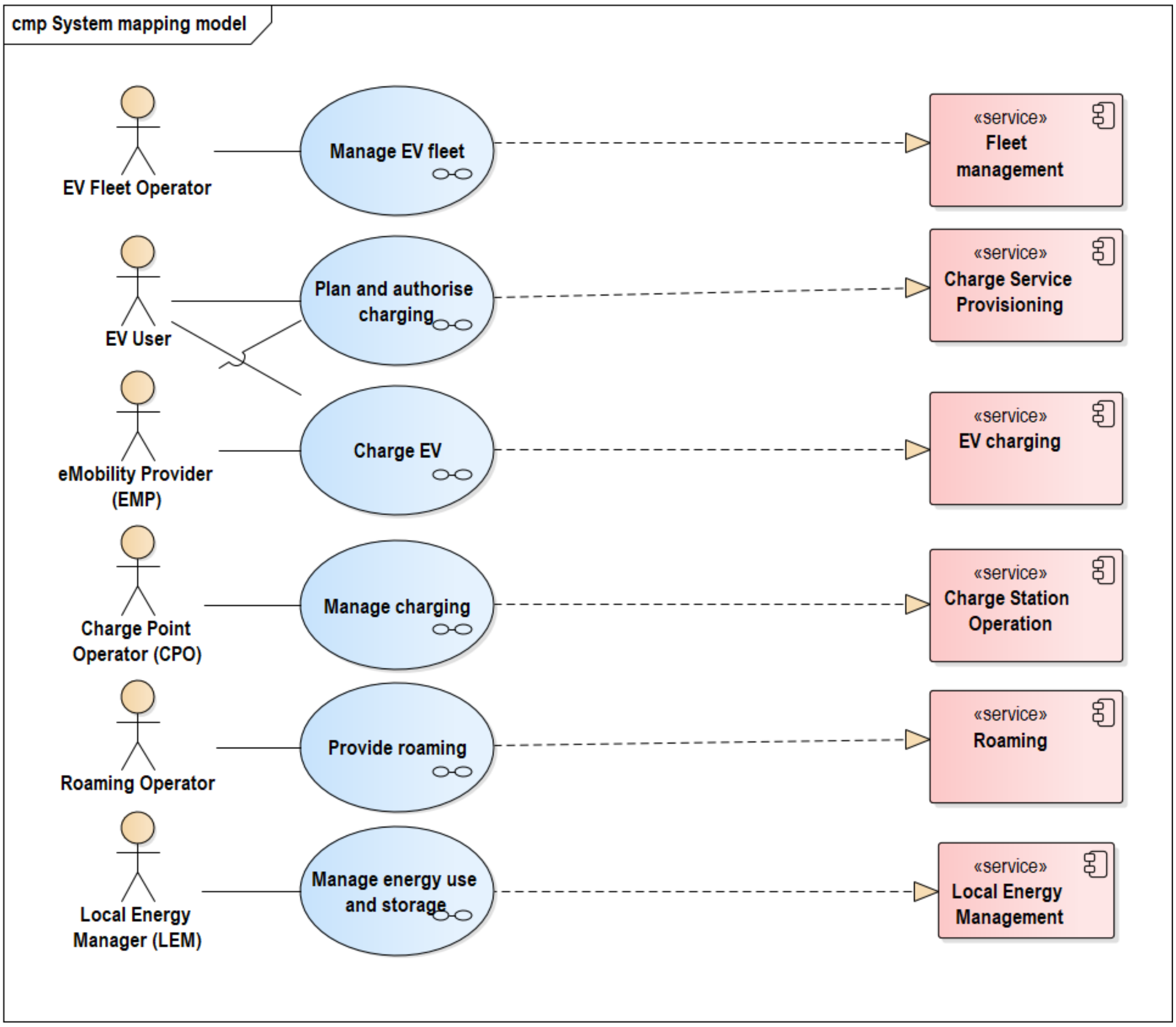

Figure 26 Use case – service mapping model

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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6.3 Environment model

The environment model in Figure 27 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.

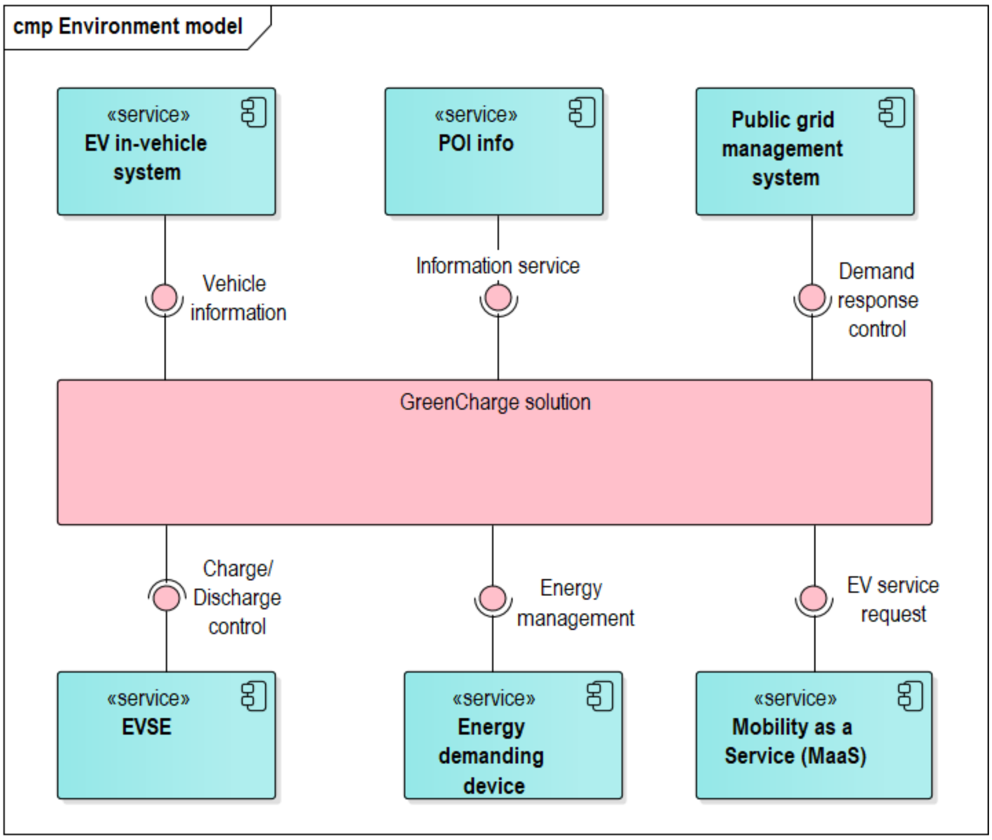

Figure 27 Environment model

The environment of the GreenCharge solution is depicted in Figure 27. The following other system components are not be further specified by this reference architecture description:

- *EV in-vehicle system.* This is the system provided by the electric vehicle (EV) manufacturer.
- *Point of interest (POI) information*: National Contact Points (NCPs) and others provide open data and information services that are needed when smart and green charging is planned and accomplished. The data may for example be charge point information, meteorological information, etc. These services may have various interfaces and may be provides by different actors.
- *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 8.2.

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

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7 Requirement view

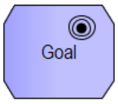
The motivation diagram in Chapter 5 identifies goals to be fulfilled from the perspective of the different stakeholder types. In this chapter, a set of overall requirements are derived from these goals, and these are further detailed.

Note that since this document is a reference architecture description, functionality that is specific to individual realisations (e.g. the design of the user interface) is not addressed. *The focus is on requirements that are 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.

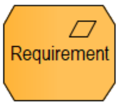
The requirements addressed are:

- Requirements regarding the GreenCharge concept.
    - The overall requirements are based on the overall goals of the following categories (see section 5.2): Local Energy Management (EM), Smart Charging (SC), EV Fleet Management (FM) and Roaming (RO).
    - The detailed requirements are based on the use case model in 6.1; input on needs from the pilots in WP2; and input on needs regarding business models identified in WP3.
- Requirements regarding the evaluation of the GreenCharge solution.
    - The overall requirements are based on the overall goals of the Research Data (RD) category (see section 5.2).
    - The detailed requirements are based on input from WP5 and WP6 on the need for automated collection of research data.
- Requirements regarding eMobility transport policies.
    - The overall requirements are based on the overall goals of the Public Policy (PP) category (see section in 5.2).
    - No detailed requirements are defined since the overall requirements do not address the technical solution.

We use the following model elements to illustrate the relations:



Goal to be met to overcome to motivate stakeholders. See section 5.



Overall requirement derived from one or more goals. The ID of such a requirement is composed of the associated topic (EM, SC, FM, RO, PP or RD) and a sequence number (e.g. SC1).

Each overall requirement, a table decomposes the overall requirement 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 6.1 (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, part of this reference architecture (any view/model).

Use of this view as a blueprint in system architecture descriptions/requirement analysis: The overall requirements (see diagrams and tables below) of relevance should be identified based on the relevant parts of the motivation model. 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.

7.1 Requirements regarding the GreenCharge concept

These requirements are linked to the implementation of the system of interest (see Chapter 3), with focus on generic requirements that are principal for the realisation of the GreenCharge concept, mainly requirements that affects the information exchange between system components. It is emphasised that this section is not meant as a complete requirements specification for a charging infrastructure, but rather as a minimal set of requirements to be implemented by a given section of charging infrastructure in order to qualify as an implementation of the GreenCharge concept.

7.1.1 Smart Charging (SC) requirements

Figure 28 shows the overall requirements derived from the goals in the Smart Charging category.

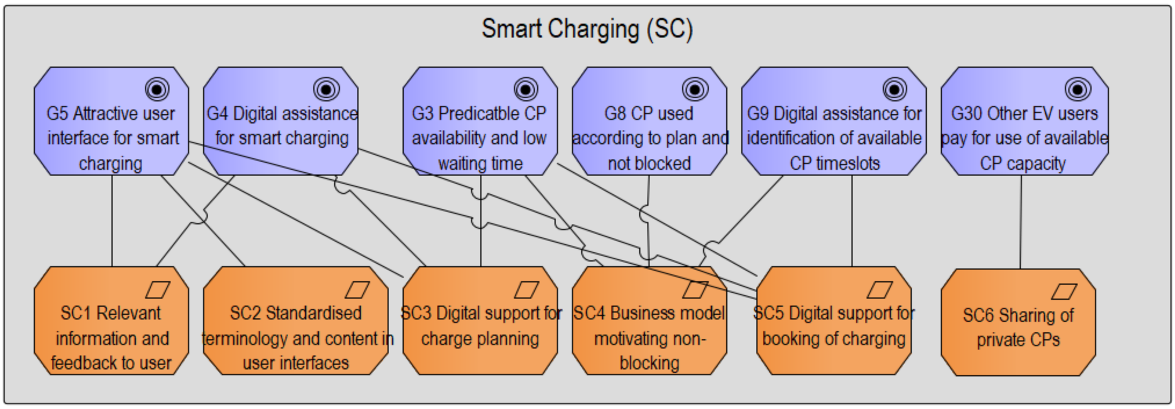


Figure 28 Overall requirements for Smart Charging (SC)

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 6.1.1: • Find CP	• Functionality • Information model • System component and interface model • Collaboration model
SC1.3	On arrival to the charge station, the EV User must get information on which charge point to use (if a charge point is booked) or on which charge points that are available.	Use case in 6.1.2: • Use CP	• 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 6.1.2: • Analyse charging Use cases in 6.1.4: • Manage charging/ discharging requests	• 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.		

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SC1.6	It must be possible to request information about the charging with respect to energy use, grid mix and savings.	• Follow up energy demands and use • Control charging process	• 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 6.1.5: • 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 6.1.2: • Use CP Use cases in 6.1.4: • Control charging process	• Information model • System component and interface model • Collaboration model
SC1.10	EV Users must get detailed billing information.	Use case in 6.1.2: • Billing and payment Use cases in 6.1.4: • 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 6.1.1: • Manage user and EV profiles and defaults • Define charging request	• 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 6.1.2: • Use 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 cases in 6.1.2: • Manage charging progress status • Billing and payment	• 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 at real time.	Pilot (OSL) Use cases in 6.1.4: • Manage charging	• Functionality • Information model • System component and interface model • Collaboration model

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SC3.3	The EV User must be authorised before the charging can be booked/used.	Pilot (OSL) Use case in 6.1.1: • Manage subscription • Authorise EV User	• Functionality • Information model • System component and interface model • Collaboration model
SC3.4	Roaming should facilitate charge planning across EMPs/CPOs. An EV User with a subscription should be able to plan charging and charge at charge points operated by "guest" CPOs, providing that the "home" EMP and CPO of the charge point are roaming endpoints.	Use case in 6.1.1: • Manage subscription • Authorise EV User • Define charging request Use case in 6.1.6: • Provide roaming	• Functionality • Information model • System component and interface model • Collaboration model
SC3.5	EV User should be able to authenticate by means of different credentials (subscriptions and common payment methods) and 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 6.1.1: • Find CP Use cases in 6.1.4: • Manage and share CP information	• Functionality • Information model • 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 6.1.1: • Manage user and EV profiles and defaults • Define charging requests Use cases in 6.1.4: • 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 - so that there will be no waiting time in 95% of cases of booking	Use cases in 6.1.4: • Control use of CPs and enforce bookings Goal from proposal KPI GC5.5in D5.1	•
SC4.2	The technology must facilitate the use of business and 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 6.1.4: • 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	Business and price models must contribute to double the utilization of charging points.	Goal from proposal KPI GC5.3 in D5.1	
SC4.6	The technology must facilitate the use of business and price models that can doubled the utilization of charging points.		

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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 6.1.1: • Find CP • Define charging request Use cases in 6.1.4: • Control use of CPs and enforce bookings	• 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 cases in 6.1.4: • Control use of CPs and enforce bookings	• 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 6.1.4: • Control use of CPs and enforce bookings	• Functionality • Information model • System component and interface model • Collaboration model

SC6 Shared private CPs			
ID	**Description**	**Source**	**Aspect**
SC6.1	The architecture must facilitate that private actors can share their private charge points. In such cases may use services offered by an EMP and the associated Charge Point Operators (CPO) to publish information about the shared charge point.	Use cases in 6.1.4: • Manage and share CP information	• Functionality • Information model • System component and interface model • Collaboration model
SC6.2	Private actors offering charging from their shared charge points act as eMobility Providers (EMPs), but they may not be in the position to establish business relations with Roaming Operators. A service from an EMP/ CPO, who has a business agreement with the Roaming Operator, must handle the roaming.	Use case in 6.1.1: • Authorise EV User • Define charging request Use cases in 6.1.4: • Manage charging/discharging requests Use cases in 6.1.2: • Manage charging progress status • Billing and payment Use cases in 6.1.4: • Control charging process	• Functionality • Information model • System component and interface model • Collaboration model
SC6.3	The shared charge point must be manged by a service provided by a CPO. This service must start and stop the charging of electric vehicles when the EV Users are authorised to use the shared charge point.		•
SC6.4	The architecture must facilitate that third parties can provide a digital service that offers the charge service and EV User support (charge planning, definition of charging request, etc.) and handle the authorisation of the EV Users charging at shared charge points.		•

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7.1.2 Local Energy Management (EM) requirements

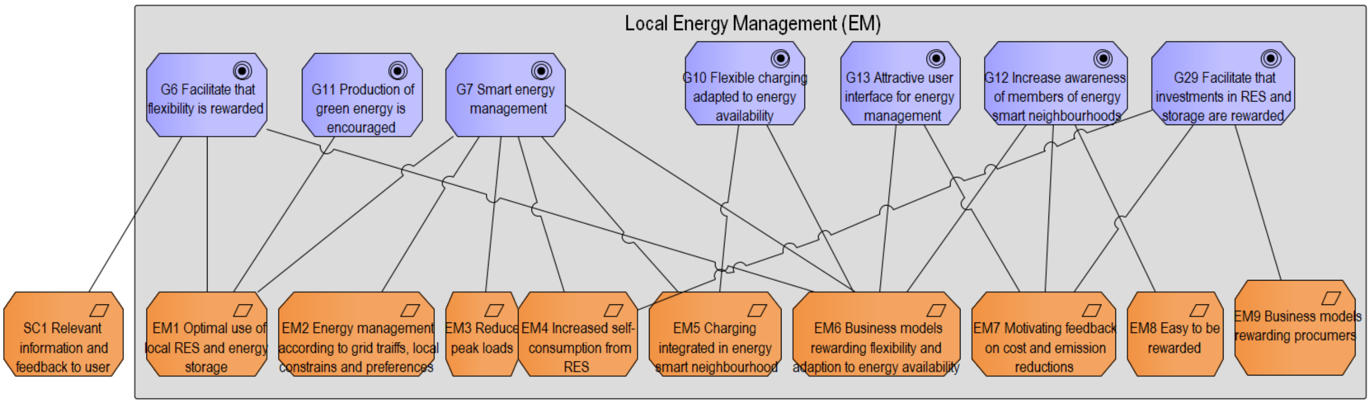

Figure 29 Overall requirements for Local Energy Management (EM)

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 6.1.5: • Predict production from local RES • Calculate energy availability • Plan optimal energy use	• 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.		
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.		
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 and facilitate a 50% increase of RES utilization	Goal from proposal KPI GC5.9 in D5.1	

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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 6.1.5: • Define rules for planning of 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 6.1.5: • Calculate 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 should provide a 20% reduction of power peak compared to a solution where no peak reduction measures are taken	Goal from proposal • KPI GC5.10 in D5.1	

EM5 Charging integrated in energy smart neighbourhood			
ID	**Description**	**Source**	**Aspect**
EM5.1	The architecture must enable hierarchical organisation of the energy management system. 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 6.1.5: • Plan optimal use of energy	• Architecture in general • Functionality • Information model • System component and interface model • Collaboration model
EM5.2	The energy management must take all loads in the neighbourhood into account when the energy use is planned.	Use cases in 6.1.5: • Plan optimal use of energy	• Functionality • Information model • System component and interface model • Collaboration model

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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. The models should facilitate that 10% of the users will allow V2G.	D3.2 Goal from proposal KPI GC5.3 in D5.1	
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 6.1.5: • Manage energy characteristics Use cases in 6.1.4: • Manage charging/discharging requests • Follow up energy demands and use Use case in 6.1.2: • Manage charging	• 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 6.1.4: • Manage and share CP information Use case in 6.1.1: • 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 6.1.4: • Manage and share CP information Use case in 6.1.1: • 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 6.1.1: • Manage user and EV profiles and defaults • Define charging request	

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<table>
<tr><th colspan="4">EM9 Business models rewarding prosumers</th></tr>
<tr><th>ID</th><th>Description</th><th>Source</th><th>Aspect</th></tr>
<tr><td>EM9.1</td><td>The amount of energy provided by RES must be recorded</td><td>Use cases in 6.1.5:
• Calculate energy availability</td><td rowspan="2">• Functionality
• Information model
• System component and interface model
• Collaboration model</td></tr>
<tr><td>EM9.2</td><td>There must be a price model for prosumers</td><td>• D3.2</td></tr>
</table>

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7.1.3 EV Fleet Management (FM) requirements

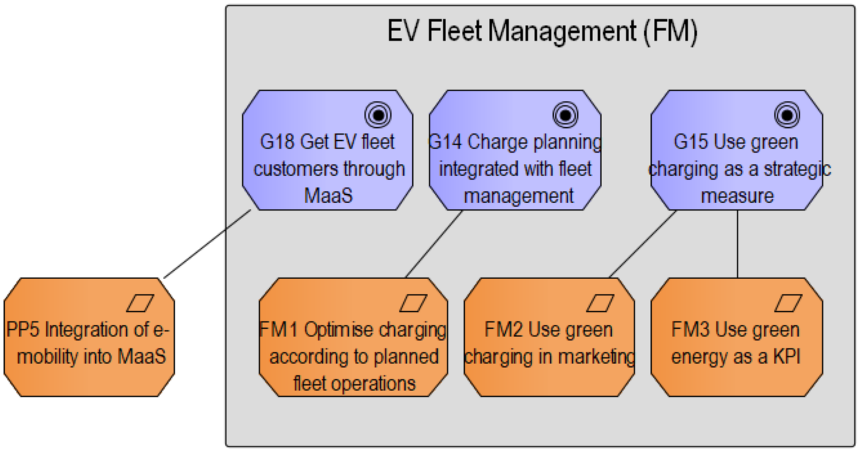

Figure 30 Overall requirements for EV Fleet Management (FM)

The following overall requirement is not further detailed since they are outside the scope of this reference architecture description or are covered by the smart charging requirements (the generic fleet management and the use of KPIs to improve this management and the marketing of the services provided by the Fleet Operator is outside the scope):

- FM2 Use green charging in marketing (it is up to the Fleet Operator to handle this as a part of the service marketing)
- FM3 Use green energy as a KPI (the Fleet Operator will however due to its role as an EV User receive information that will facilitate the use of such KPIs - see SC1.7 and SC1.8)

As illustrated in Figure 5, the EV Fleet Operator is a specialisation of the EV User. Thus, several of the requirements provided on Smart charging are relevant regarding EV fleet management. These requirements are not repeated here.

The main difference between the charge planning of EV Users and EV Fleet Operator probably is that the EV Fleet Operator may have more long-term information on charging needs, and they might be able to provide input on energy demands a long time before the actual use of the energy.

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.	Pilot (BCN) Use cases in 6.1.3: • 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.		
SC1	**SC1 Relevant information and feedback to user**	• See section 7.1.1.	
SC3	**SC3 Digital support for charge planning**		
SC5	**SC5 Digital support for booking of charging**		

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7.1.4 Roaming (RM) requirements

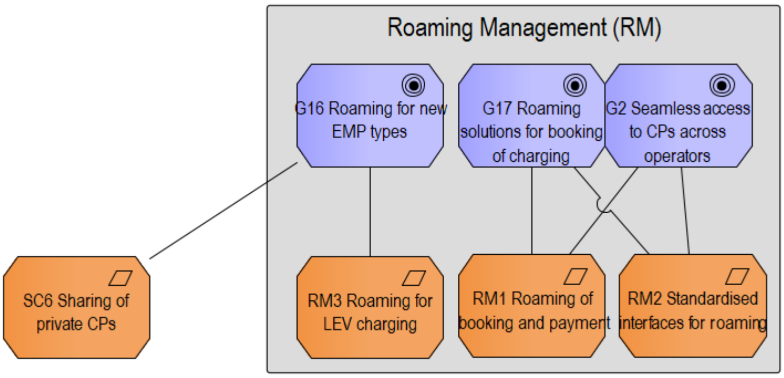

Figure 31 Overall requirements for Roaming Management (RM)

RM1 Roaming of booking and payment			
ID	**Description**	**Source**	**Aspect**
RM1.1	Roaming must facilitate booking of charging and energy across eMobility Providers (EMPs)/Charge Point Operators (CPOs). An EV User should be able to use the booking/ access/ payment service provided by his/her home EMP also to book/get access to charge stations managed by other EMPs.	Use case in 6.1.1: • Authorise EV User • Define charging request Use case in 6.1.6: • Provide roaming Use cases in 6.1.2: • Manage charging progress status • Billing and payment Use cases in 6.1.4: • Control charging process	• 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 6.1.6: • Provide 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 6.1.1: • Plan and authorise charging Use case in 6.1.2: • Charge EV Use cases in 6.1.4: • Manage charging Use case in 6.1.6: • Provide 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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7.1.5 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 • Realisation 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 • Realisation 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 • Realisation view

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7.1.6 Interfaces requirement (IR)

The requirements regarding the interfaces between the services in section 6.2 and 6.3 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 7.1.1	• 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 7.1.2	• System component and interface model • Collaboration model
IR5	For interaction between electric vehicle charging and Charge station 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 6.3 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

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7.2 Requirements regarding evaluations

A GreenCharge system must collect data from the pilot sites to support the evaluation of how the system performs. This will be

- Data needed with respect to the KPIs defined by WP5 and WP6.
- Data needed as input to simulations investigating further potential performance in other contexts, as defined by WP5.

The data collection must be harmonised across the pilot sites.

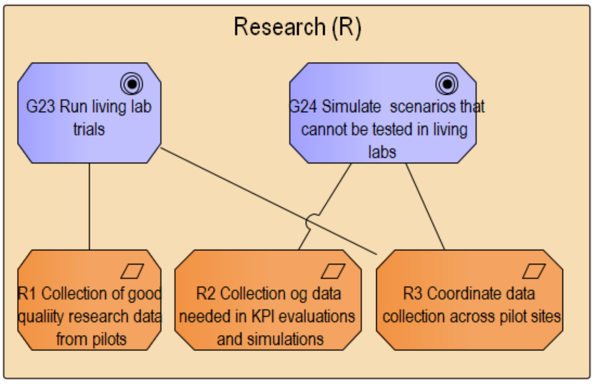

Figure 32 Overall requirements for Research (R)

Requirements regarding data needed are defined by WP5 and WP6 and will not be further addressed here.

The data to be collected is described in section 8.1.3.

7.3 Requirements regarding transport policies

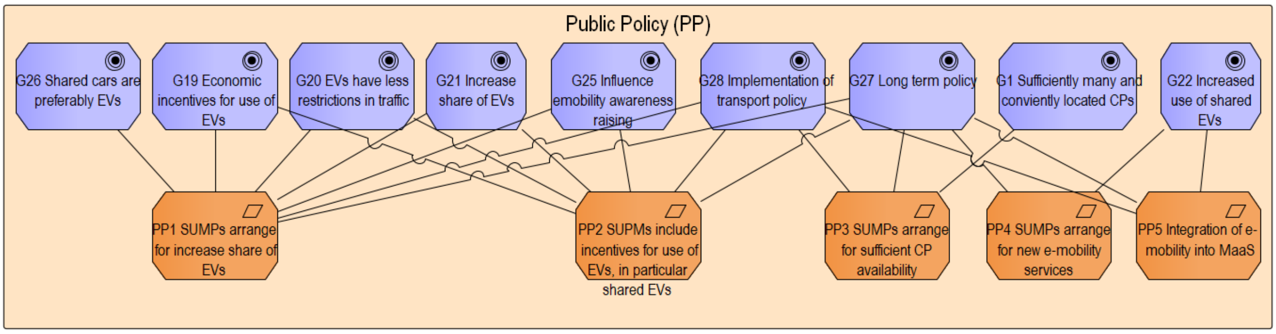

Figure 33 Overall requirements for Public Policy (PP)

The requirements regarding transport policies will not affect the digital solution and are not further elaborated in this deliverable. The requirements are input to WP7.

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8 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.

8.1 System Information model

The high-level information elements are defined by UML class diagrams. The model also covers the research data needed in simulations and evaluations.

Use of this model as a blueprint in system architecture descriptions: The information model addressed the information that is exchanged between the systems and should preferably not be changed. Based on the need for interaction with other systems, the information elements of relevance should be identified. Internally, the system may use other and different information elements.

Figure 34 provdes an overview of the information elements which are the basis for the information exchanged between the services and the research data collection. The information elements are then split into two subsets and shown with attributes in Figure 35 and Figure 36.

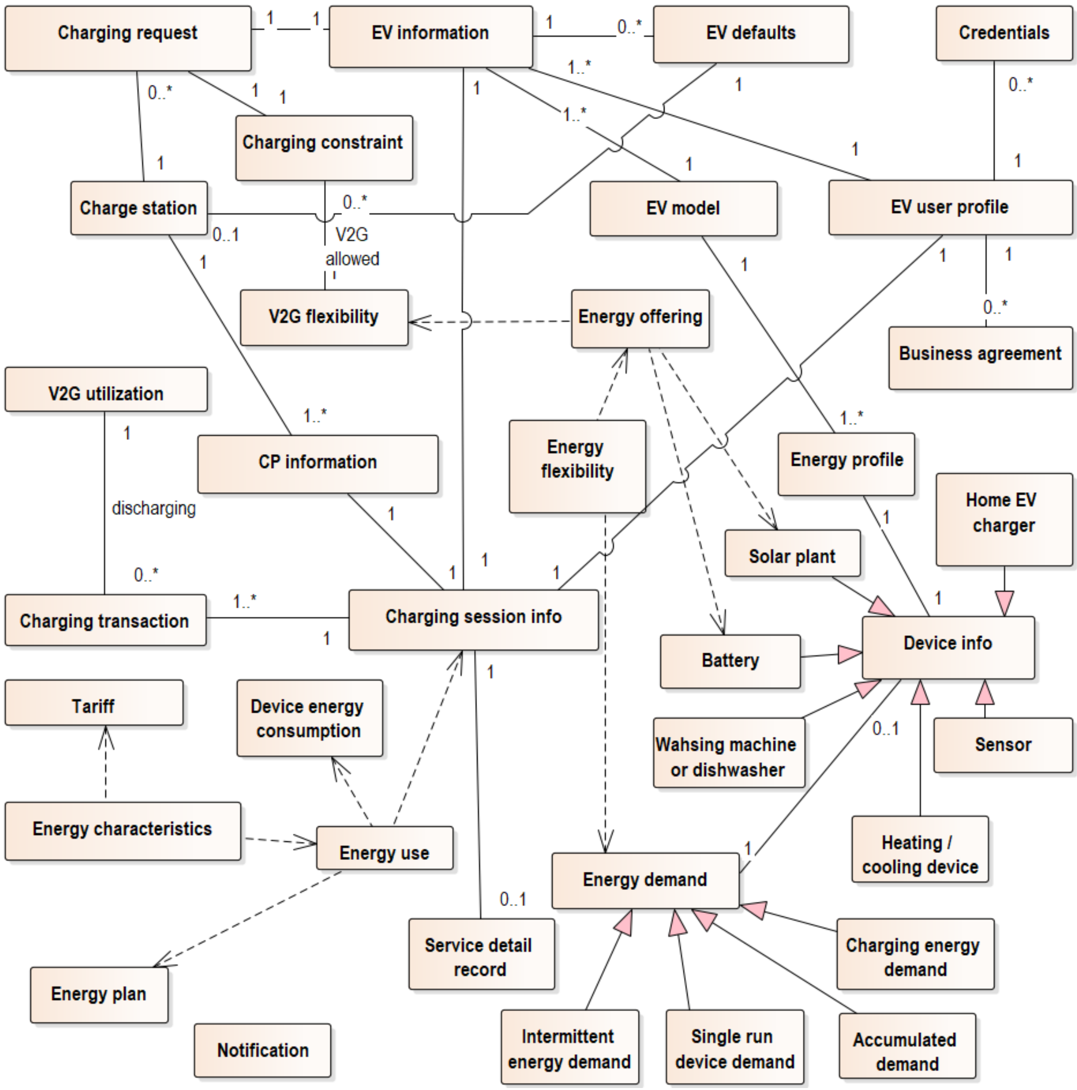

Figure 34 Overall information model

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8.1.1 EV information model

Figure 35 shows the information elements related to EV.

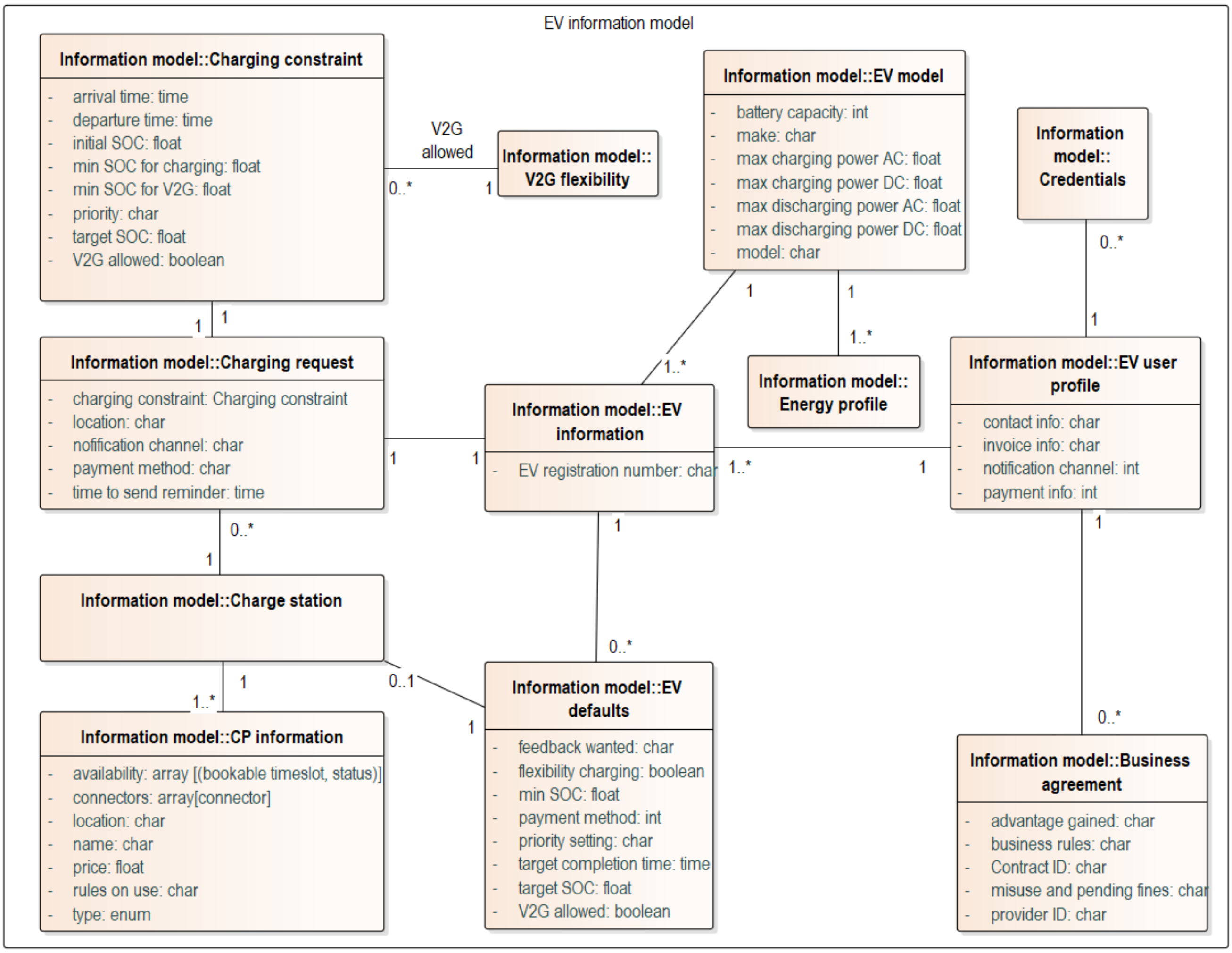

Figure 35 EV information model

Each EV has an **EV information** element with its registration number. It has

- An **EV model** element describing the EV make and model (e.g., VW e-Up!) and properties such as battery capacity (kWh), maximum charging and discharging power in AC (kW), and maximum charging and discharging power in DC (kW). Each EV model is associated with **Energy profiles** for charging or discharging.
- **EV defaults**, which is a collection of default settings. There may be different defaults for different charge stations (at home, work, favourite shopping centre, etc. Typically, EV defaults consist of minimum State-of-Charge (SoC), target SoC, target completion time for reaching the target SoC, priority setting, default payment method, flags indicating if flexible charging and V2G is allowed (yes or no) and flags indicating the feedback wanted on the charging process.
- An **EV user profile** element with invoice and payment information, user's contact info and notification channel (email, SMS, etc) and **Credentials** to authenticate the user in order to access the systems. A user may have several **Business agreements** with different providers. A business agreement describes a business contract with a provider and information about the advantage gained (extra time, etc), misuse and pending fines, and business rules (incentives, etc). An EV user may be associated with several EVs. and for each EV the user may have default settings for each EV.

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- A **Charging request** linked to a **Charge station**. The **Charging request** element specifies the location for charging and charging constraint, payment method, notification channel (email, SMS) and the time to send reminder before charging. The **Charging constraint** specifies the EV arrival and departure time, the initial SoC at arrival, the minimum SoC and target SoC for charging, the priority setting and if V2G is allowed. In case of the latter, a **V2G flexibility** element provides the energy offering provided by V2G from all the EVs.

A **Charge station** has one or several Charge points (CPs). Each CP is described using **CP information** and contains information about the name, location and type of the CP (normal, semi-fast, fast, or super charger), the connectors provided, the price and rules on use, and a list of bookable timeslots with status (available or booked).

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8.1.2 Energy management information model

Figure 36 shows information elements related to energy offering, demand and use.

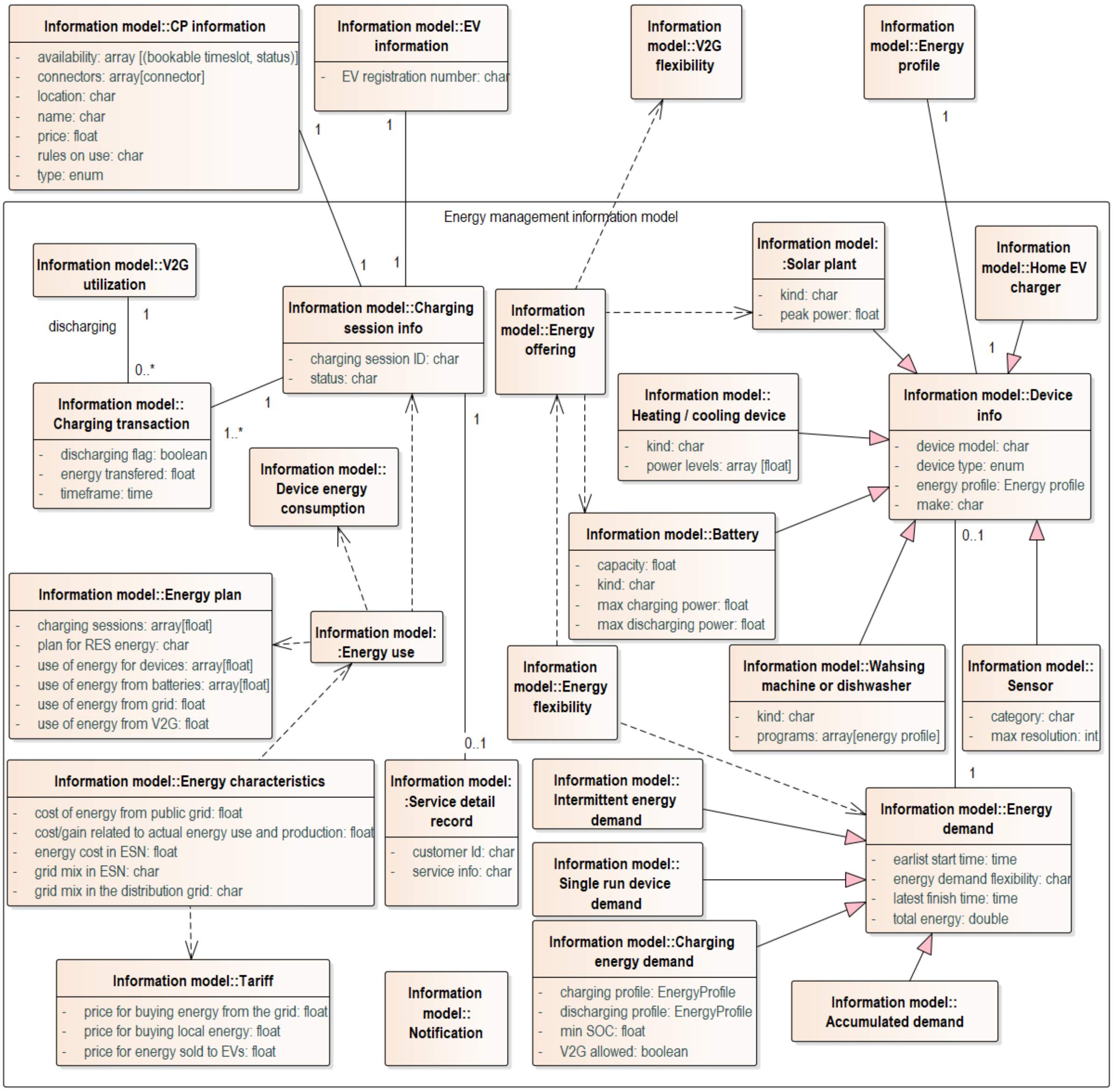

Figure 36 Energy management information model

In addition to the energy offered by the power grid, **Energy offering** considers the energy produced by local RES (e.g., solar plant), local storage (i.e. battery) and the V2G flexibility offered by EVs.

Energy demand represents the energy required by the energy demand activities to be managed, including

- energy demanding activities from devices: **Single run device demand** (for washing machines and dishwashers), **Intermittent energy demand** (for heating/cooling devices);
- electric vehicle charging bookings with time constraint: a list of booking requests (**Charging energy demand**) or aggregation of them (**Accumulated demand**).

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.

Energy plan is an optimal plan for the use of energy. The following is considered:

- energy from the power grid

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- energy from battery
- energy from V2G when the grid and RES capacity is not enough
- what to do with energy from RES
- energy demand from energy demanding devices and charging sessions.

The total energy plan for a charge station, can be the total energy capacity plan specifying the energy constraints (maximum power, maximum energy, etc) for a timeframe.

Energy use is based on the energy plan. There are two types of energy use: the charging of EVs represented by charging sessions, and the energy consumed by energy consuming devices.

A charge point may have several charging sessions. A **Charging session information** provides information for a charging session carried out by a charge point for an EV and contains a collection of charging transactions. It contains the charging session ID and the status. A **Charging transaction** describes the energy transferred within a timeframe, and if discharging is allowed, the energy for V2G. The V2G utilization of the ESN is the total energy provided by V2G from all the EVs in the ESN within a timeframe.

A **Service detail record** provides service information for charging session and is the basis to calculate the cost for the energy use. The detailed information is described in the "Manage charging" use case in 6.1.4.

Energy characteristics provides information on the variation of energy properties over time, including the cost of energy from public grid, the grid mix in the distribution grid, the energy costs for the energy used, the grid mix for the energy, and the costs/gains related to actual energy use and production.

Tariff defines price models and provides information on the prices for buying energy from the public grid, for buying local energy and for energy sold to EVs. It is the basis for calculating the cost of energy use.

Demand response control is an input from the DSO when LEM calculates the energy flexibility for the ESN.

The **Device info** provides the description of monitored devices in the ESN with their characteristic properties. Individual devices of a particular model have the same properties. We classify the devices into the following categories and describe the common properties for each category:

- **Sensor**: A device measuring something, for example a smart meter or a temperature sensor. Described using *category* defining the kind of sensor and *max resolution* for the data sampling rate per second.
- **Heating/cooling device:** A device maintaining a given temperature in an enclosed space, e.g. Electric heater, Air conditioner, Heat pump, Water boiler, Refrigerator, Freezer. Described using *kind* (such as Electric heater) and the *power levels* as a list of float/kW as some devices can operate at different power levels.
- **Washing machine or dishwasher:** Described using *kind* (washing machine, dishwasher) and *programs* represented by a list of energy demand profile.
- **Solar plant:** Described using *kind* and the *peak power* in kW.
- **Battery:** The stationary battery described using *kind*, *capacity* in kWh and *max. charging power* and *max. discharging power* both in kW.
- **Home EV charger:** Treated as a charge point and described using information element *CP information*.

Notification is the message given to the user or from user about the status and feedback on the system and the charging process.

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8.1.3 Research data collected by systems

In order to support the evaluation of achievable impacts of the GreenCharge solution on the KPIs defined for the project, the pilots will need to collect necessary research data. Moreover, since as foreseen in the DoA, the pilots will be only partial and small-scale implementations of the GreenCharge concept, we will use simulations based on data collected by the pilots to investigate in more depth the possible impacts of the GreenCharge kind of smart charging and energy management systems in different contexts and scales.

In this section we describe the data that must be collected by the pilots for this purpose. We will need to collect basically three kinds of data,

- Data about the makes and models of the devices/hardware involved in the demonstrators. These are devices/hardware such as heating/cooling devices, washing machines/dishwashers, PVs, batteries, sensors, and EVs.
- Data about individual entities involved (i.e. systems, devices/hardware and price models). They will get unique identifiers and they will be described (through references to makes and models or by data elements). The devices/hardware are heating/cooling devices, washing machines/dishwashers, PVs, batteries, sensors, Charge stations, Charge points, and EVs.
- Log entries will refer to the above systems/devices/hardware and price models through use of unique identifiers.

The data about makes and models and data about the individual entities will be static data registered in advance. The log entries will be provided during execution of the demonstrators

Table 13 provides a summary of information about the research data to be collected.

- Column one provides an overview of what the makes and models and the individual entities will be addressing.
- The next two columns show the categories of makes and models and individual entities addressed that will be addressed. If there are x-es in both columns, the information about the individual entities will refer to the relevant make and model.
- The last five columns are the type of logs that are provided. The logs may refer to the selected individual entities.

Table 13 Overview of research data to be collected

Type of makes and models/ individual entities	Registered in advance		Logs			
	Make and model	Individual entities	Charge booking and energy consumption in charging	Other energy consumption and production	Energy charac-teristics	Metero-logical issues
Software systems		x	x	x	x	
Heating/cooling devices	x	x		x		
Solar plants	x	x		x		
Batteries	x	x		x		
Washing machine/ dishwashers	x	x		x		
Sensors	x	x				x
EVs	x	x	x			
Charge stations		x	x			
Charge points		x	x			
Energy meters		x			x	
Price models		x	x		x	

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8.1.3.1 Data on makes and models

Data about the equipment involved in the pilots must be collected. We need a common scheme for uniquely identifying both makes and models. The make and model will be a unique identifier where the model is supposed to be unique within a make and including any variant info justifying a separate description, e.g. AEG Lavamat 7000 (a washing machine), VW e-Up! (an electric vehicle) or Tesla S 75D (another electric vehicle with battery capacity included to distinguish between Tesla model S with different battery sizes). The make and model will be described by means of the information elements defined in the information models in 8.1.1 and 8.1.2.

Makes and models for	Description	Data needed – see information model
Heating/cooling device	Each heating and/or cooling device monitored in the pilot	Device info attributes Heating/cooling device attributes
Solar plant	Each solar plant monitored in the pilot	Device info attributes Solar plant attributes
Battery	Each solar plant monitored in the pilot	Device info attributes Battery attributes
Washing machine or dishwasher	Each battery monitored in the pilot	Device info attributes Washing machine or dishwasher attributes
Sensor	Each sensor used to monitor the pilot	Device info attributes Sensor attributes
EV model	Each electric vehicle model involved in the pilots	EV model attributes

8.1.3.2 Data on individual entities

We need a common scheme for uniquely identifying individual entities (hardware and software artefacts) involved in the pilots for which we will be collecting data, and maybe also for some stakeholders and less tangible artefacts for contracts and tariffs (e.g. price models).

We need unique identifiers for each entity and references to relevant makes and models (see 8.1.3.1) and information elements defined in the information models in 8.1.1 and 8.1.2.

Individual entities registered for	Unique id	Data needed – see information model attributes
Software system	System id	
Heating/cooling device	Device id	Link to make and model
Solar plant	Device id	Link to make and model
Battery	Device id	Link to make and model
Washing machine/ dishwasher	Device id	Link to make and model
Sensor	Device id	Link to make and model
EV	EV registration number, national code included	Link to make and model
Charge station	Charge station id	IDs of the charge points
Charge point	Charge point id (unique within the charge station)	CP information attributes
Energy meter	Device id	
Price model	Price model id	Business agreement attributes

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8.1.3.3 Logs on charge booking and energy consumption in charging

Data must be collected on charge bookings and actual EV charging. The data is represented as time series stored in a CSV file recording accumulated energy (kWh) or used power (kW).

Log records	Collected information	Collect for
Records on booking and charging activity	**Source:** System id of system providing log entry **Kind**: (Initial booking, booking adjustment, arrival, departure) **Session**: Energy management information model. Charging session info.Charging session ID **Energy demand**: Energy management information model.Charging energy demand attributes Energy management information model.Charging constraints attributes **Outcome**: Energy management information model.Service detail record	Each charge booking and charging event throughout the operational period of the pilot One log per charge station.

8.1.3.4 Logs on energy consumption and production

Data must be collected on

- Energy consumption for all consuming entities
- Energy production for solar plants
- Both consumption and production (while discharging) for batteries

The data is represented as time series stored in a CSV file recording accumulated energy (kWh) or used power (kW).

Log records	Collected information	Collect for
Records on energy consuming or producing behaviour during pilot operation	**ID:** The identifier of the entity **Logged data:** energy demand attributes time series with timestamps and accumulated energy use/production (kWh) or power (kW)	All devices monitored in the pilots

The energy demand may include information on the flexibility of the energy demand. For example, acceptable deviation from setpoint temperatures and acceptable duration of pauses in the running of heating/cooling devices and acceptable delays. We need it for assessing the achievable impact of local energy management in neighbourhoods on energy consumption, energy mix, peak power, energy cost and CO2 emissions. For charging it will be collected through the charging app.

The resolution of the energy use/production measurement depends on the device types and may vary from 1 minute to 1 hour.

Data	Sampling rate
Energy production per RES (kWh)	Every 5th min
Energy used/ stored (kWh) per device during operation time	Every 5th min
Energy stored in stationary battery (KWh)	Every 5th min
Energy used from stationary battery (KWh)	Every 5th min
Energy used from EV battery for each session (each connection time) with V2G (kWh)	Every 5th min

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8.1.3.5 Logs on energy characteristics

The data in these logs are measured by main meters, and they will log both export and import of energy to and from the distribution grid, grid energy mix (%) and tariffs/prices (EUR)

The logs provide time series with resolutions as suggested below.

Data	Sampling rate
Export kWh	Every 5th min
Import kWh	Every 5th min
Price tariffs (EUR). Sampling rate depends on how often the tariff will change (min rate is 1 per hour, max rate is 1 per day)	Hourly
Energy mix in public grid (%)	Monthly

8.1.3.6 Logs on meteorological issues

Inside temperature in heated/cooled spaces

We should collect this data to derive flexibility of such loads (spaces heated/cooled by a controlled device). This is temperatures represented as time series.

Data to be logged	Sampling rate
Inside temperature (C°)	Hourly

Weather data

With same rationale as above, we should log both predicted (for at least 1 day ahead if data is available) and measured weather data represented as time series.

Data to be logged	Sampling rate
Predicted outside temperature (C°)	Every 5th minute
Predicted insolation (kWh/m²)	Every 5th minute
Predicted wind (m/s)	Every 5th minute
Predicted precipitation (mm/hour)	Every 5th minute
Measured outside temperature (degrees Celsius)	Every 5th minute
Measured insolation (kWh/m²)	Every 5th minute
Measured wind (m/s)	Every 5th minute
Measured precipitation (mm/hour)	Every 5th minute

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8.2 System component and interface model

Figure 37 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 used for communication. These services and the mapping from use cases to services have been described in 6.2.

Note that the GreenCharge system is modelled as a set of collaborating services that are meant to be implemented by modifying and extending existing systems. This means that the architecture does not enforce a particular structure on the set of participating systems.

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

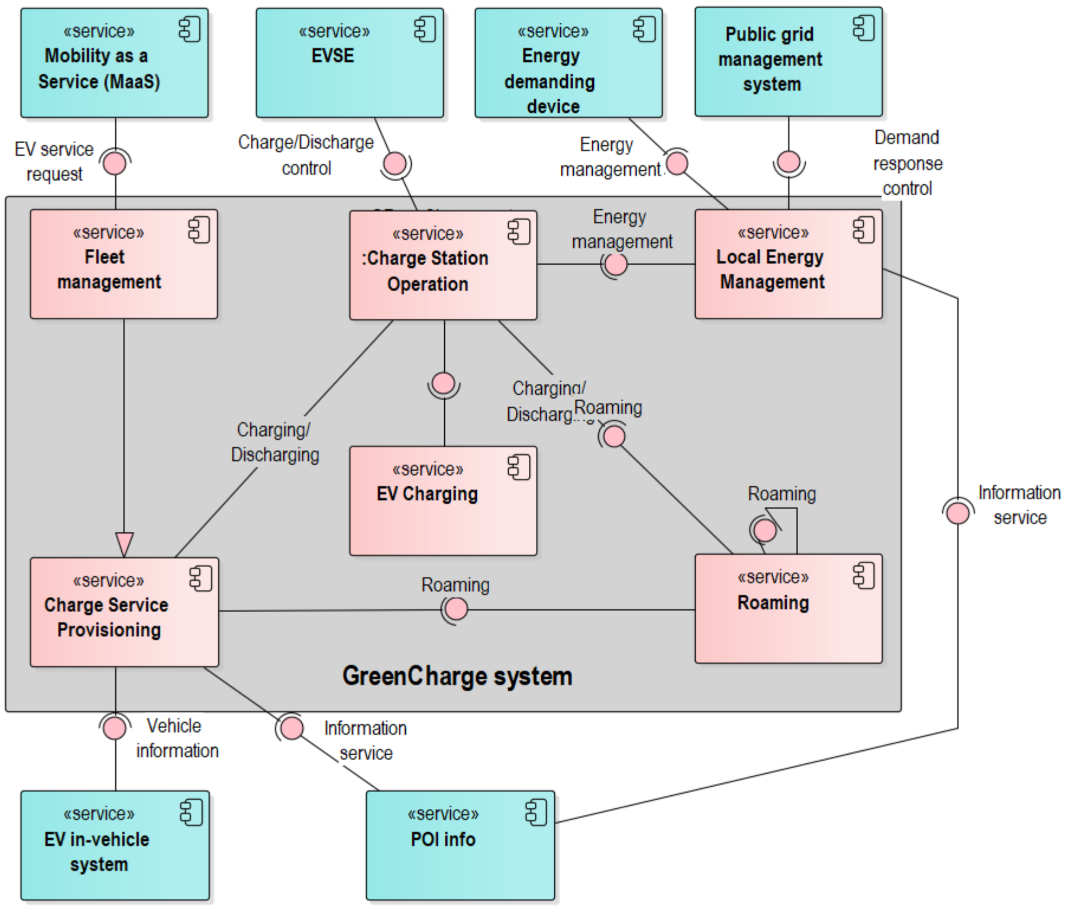

Figure 37 High level logical components and interfaces

The interfaces provided by the external components are:

- *EV service request.* This interface is decided by the EV Fleet Operator and/or the MaaS operator and is not further described here.
- *Charge/Discharge control*. According to the requirements provided in 7.1.6, this interface must be realised as defined by the Open Charge Point Protocol (OCPP 2.0) standard.
- *Demand response control*. This interface is decided by the Distribution System Operator (DSO) and is not further described here.
- *Vehicle information.* According to the requirements provided in 7.1.6, this interface must be realised as defined by the OBD2 standard
- *Information service.* This interface is decided by Point of Interest (POI) information provider and is not further described here.

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

- *Charging/Discharging* interface provided by the Charge Station Operation service. According to the requirements provided in 7.1.6, this interface must be based on the ISO 15118 Road vehicles - Vehicle to grid communication interface. The messages needed are however defined below and may include additional aspects due to the novelty of the GreenCharge concept.
- *Roaming* interface provided by the Roaming service. According to the requirements provided in 7.1.6, this interface must preferably be realised according to IEC 63119 and IEC 63119-1 ED1 – Information exchange for Electric Vehicle charging roaming service (when ready). The messages needed are however defined below since the standard is not yet ready and since the novelty of the GreenCharge concept must be supported.
- *Energy management* interface provided by the Local Energy Management service.

The messages transferred via the interfaces provided by the internal logical components/services are described below.

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 6.2). The associated messages should be used.

8.2.1 Charging/Discharging interface

Table 14 Messages communicated via Charging/Discharging interface

Message	From component	To component	Message data	description (comments)
CS info request	Charge Service Provisioning	Charge Station Operation	CP information	Get information about the charge station and the associated CPs
Authorization request	EV charging	Charge Station Operation	CP information; Credentials	Authorization request in order to get access to CP
Authorization response	Charge Station Operation	EV charging	Charging session info	Session status indicates if the access is granted or rejected
Charging request	Charge Service Provisioning	Charge Station Operation	Charging request; Charging session ID	Charging request with details and constraints. Can create, update or cancel a charging request.
Charging response	Charge Station Operation	Charge Service Provisioning	Charging session info	Session status indicates if request is approved or denied
Start charging	EV charging	Charge Station Operation	Charging session info	Start a charge session
Status request	EV charging	Charge Station Operation	Charging session info	Get charge status
Status response	Charge Station Operation	EV charging	Charging session info; Current SoC	Difficult to get SoC today

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Status notification	Charge Station Operation	EV charging	Charging session info; Message to user (Notification)	Deviation notifications included
Charging completed	Charge Station Operation	EV charging	Service detail record (SDR)	Return SDR when charging is completed or when EV is disconnected
Ready to leave	EV charging	Charge Station Operation	Charging session info	When electric vehicle is disconnected

8.2.2 Energy management interface

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

Table 15 Messages communicated via Energy management interface

Message	From component	To component	Message data	description (comments)
Energy request	Charge Station Operation Energy demanding devices	Local Energy mgmt.	Charging session info; Energy demand	The energy demand for a charging session. The message will be forwarded to LEM at the higher or lower level in hierarchical energy management (same for all the other messages).
	Local Energy mgmt..	Local Energy mgmt.		
Energy response	Local Energy mgmt.	Charge Station Operation; Energy demanding devices	Energy plan	May include charging and V2G. When the request is accumulated demand, the response will be the total energy profile.
	Local Energy mgmt..	Local Energy mgmt.		
Energy offerings	Local Energy mgmt..	Local Energy mgmt.	Energy offering	For calculation of energy flexibility in the hierarchical energy management.
Energy flexibility	Local Energy mgmt..	Charge Station Operation	Energy flexibility	Info about the energy flexibility

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		Energy demanding devices		
	Local Energy mgmt..	Local Energy mgmt.		
Energy characteristics report	Local Energy mgmt.	Charge Station Operation	Energy characteristics	Based on the logs of energy use
Energy use report	Charge Station 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.		

8.2.3 Roaming interface

Table 16 Messages communicated via Roaming interface

Message	From component	To component	Message data	description (comments)
CS info request	Charge Station Operation	Roaming	CP information	Get information about the charge station and the associated CPs
	Roaming	Roaming		
Put CP information	Roaming	Charge Station Operation	CP information	Update information about the charge station and the associated CPs
	Roaming	Roaming		
Share credentials	Charge Service Provisioning	Roaming	Credentials	Share credentials of registered EV users
Authorisation request	Charge Service Provisioning	Roaming	CP information; Credentials	Authorization request in order to get access to CP
	Roaming	Roaming		
Authorisation response	Roaming	Charge Service Provisioning	Charging session info	Session status indicates if the access is granted or rejected
	Roaming	Roaming		
Charging request	Charge Service Provisioning	Roaming	Charging request; Charging session ID	Charging request with details and constraints. Can create, update or cancel a charging request.
	Charge Station Operation	Roaming		
	Roaming	Charge Service Provisioning		

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	Roaming	Charge Station Operation		
	Roaming	Roaming		
Charging response	Charge Service Provisioning	Roaming	Charging session info	Session status indicates if request is approved or denied
	Charge Station Operation	Roaming		
	Roaming	Charge Service Provisioning		
	Roaming	Charge Station Operation		
	Roaming	Roaming		
Start charging	Charge Service Provisioning	Roaming	Charging session info	Start a charge session
	Roaming	Charge Station Operation		
	Roaming	Roaming		
Status request	Charge Service Provisioning	Roaming	Charging session info	Get charge status
	Roaming	Charge Station Operation		
	Roaming	Roaming		
Status response	Charge Station Operation	Roaming	Charging session info; Current SoC	When request is approved or denied (if the response goes via the Roaming Operator) Difficult to get SoC today
	Roaming	Charge Service Provisioning		
	Roaming	Roaming		
Status notification	Charge Station Operation	Roaming	Charging session info; Message to user (Notification)	Deviation notifications included
	Roaming	Charge Service Provisioning		
	Roaming	Roaming		
Charging completed	Charge Station Operation	Roaming	Service detail record (SDR)	Return SDR when charging is completed or when EV is disconnected
	Roaming	Charge Service Provisioning		
	Roaming	Roaming		
Ready to leave	Charge Service Provisioning	Roaming	Charging session info	When electric vehicle is disconnected
	Roaming	Charge Station Operation		
	Roaming	Roaming		

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.

8.3 System collaboration model

The interactions between the system components are on the next pages described by means of behaviour diagrams (UML sequence diagrams and/or process diagrams).

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.

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.

8.3.1 Plan and prepare charging

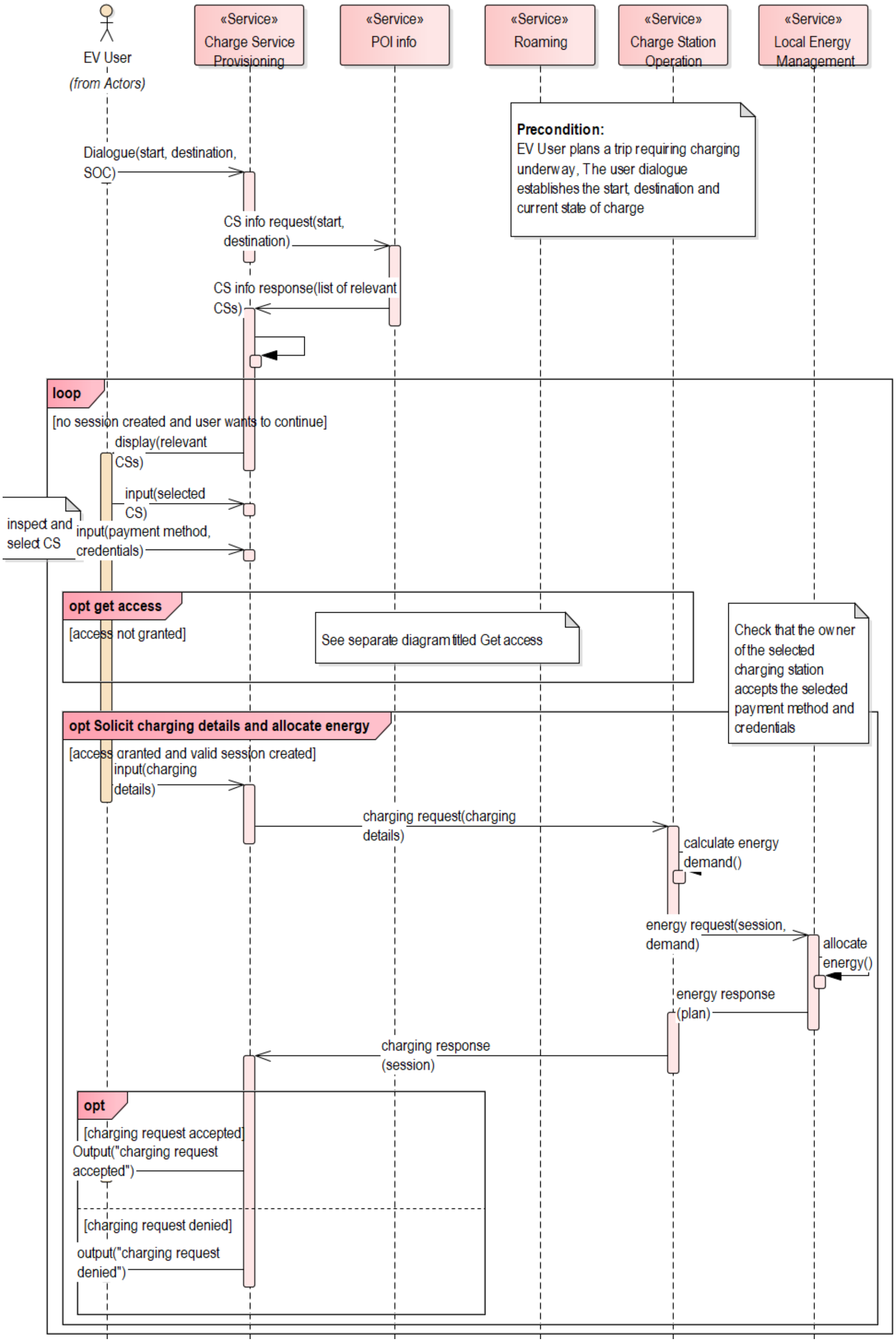

Figure 38 Plan and prepare charging

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8.3.2 Get access to charge point (CP)

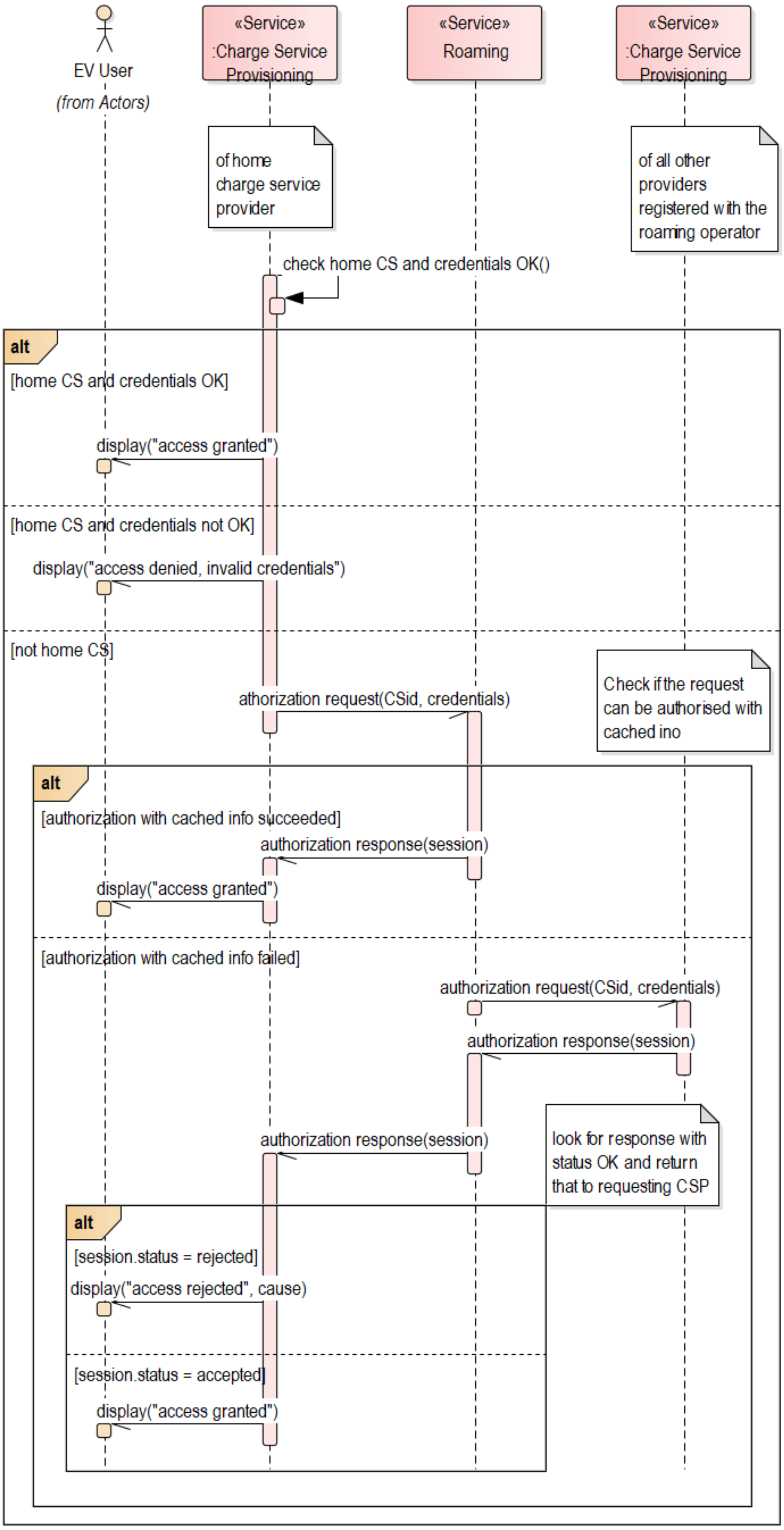

Figure 39 Get access to charge point (CP)

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.

8.3.3 Charging at booked charge station

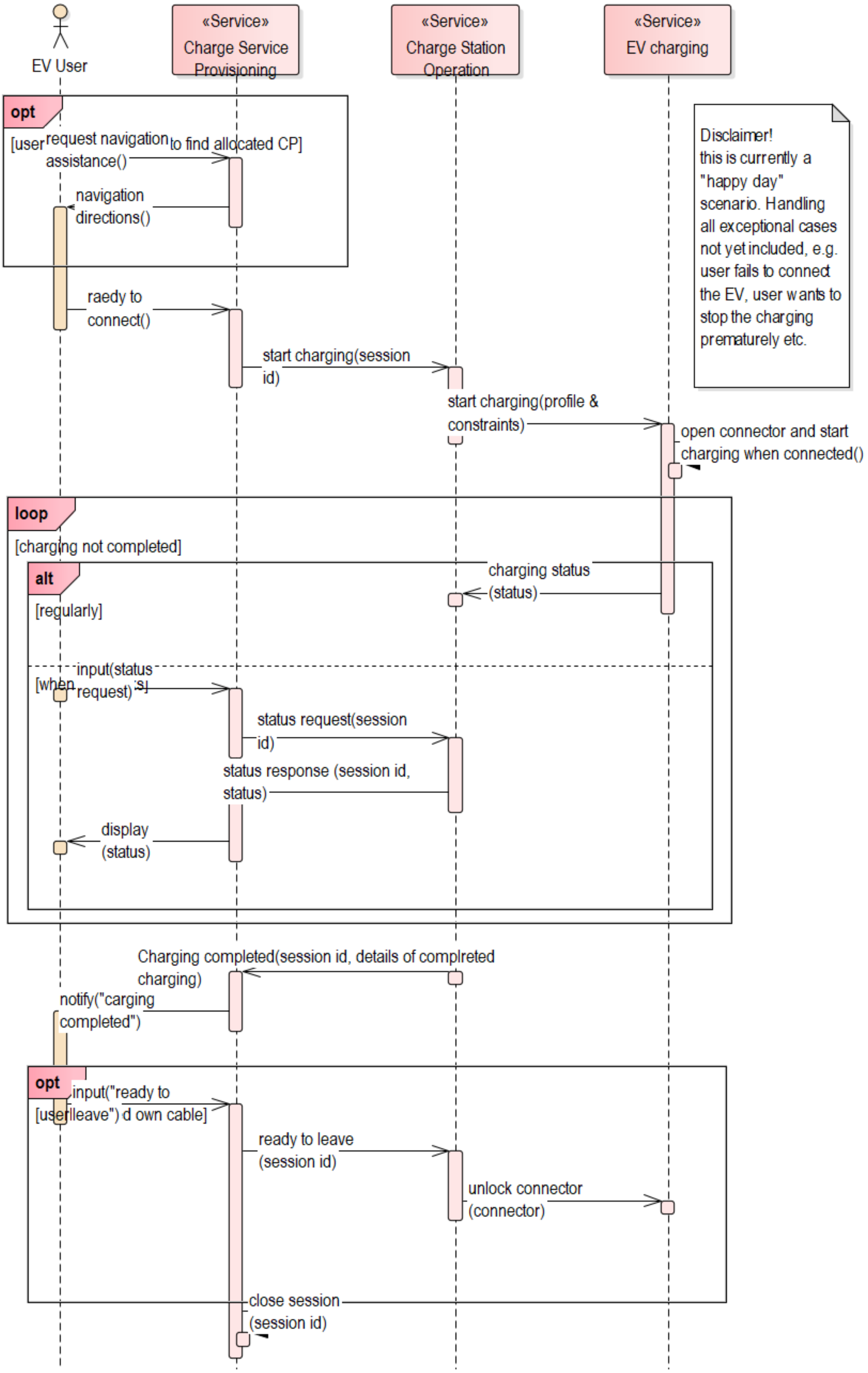

Figure 40 Charging at booked charge station

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8.3.4 Hierarchical 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 system of a charge station, and the charge station operation.

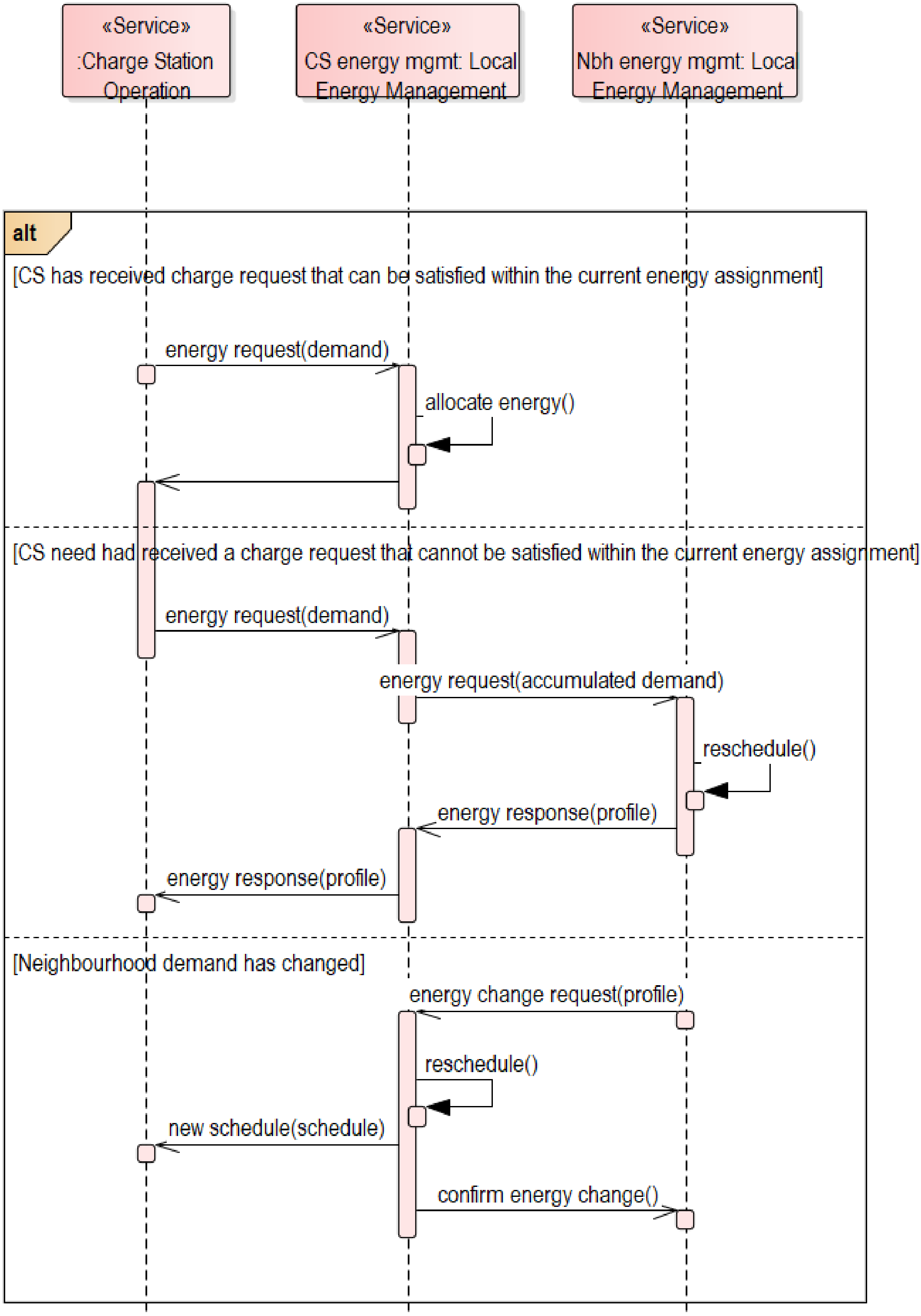

Figure 41 Hierarchical local energy management

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.

9 Distribution view

This reference architecture description does not define the distribution of software and hardware components into systems. These issues must be decided by the system owners.

Use of this view in system architecture descriptions: Use a System Distribution Model to describe how the logical components (use cases, services, etc.) will be realised by real system components and deployed together. The following will be considered:

- System size (number of components and interfaces involved)
- Geographical distribution of components
- Communication properties
- Data processing capacities
- System collaboration – which components are interacting with each other
- Transparency with respect to access, failure, location, migration, relocation, replication, persistence and transaction.

The interfaces to be implemented should be identified (from the

System component and interface model in section 08.2).

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10 Realisation view

This reference architecture description does not define the realisation of the issues addressed. The realisation into target systems and how these target systems should be implemented and deployed into their environments must be decided by the system owners.

Use of this view in system architecture descriptions: We recommend that the system owners define

- System Deployment Model – to describe the set of system deployment configurations.
- Technology Mapping Model – to describe how system components maps to technological solutions, concepts and mechanisms.
- System Integration Test Model - to describe the test scenarios to be conducted during system deployment.

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11 Conclusion

11.1 Supporting the GreenCharge idea

The reference architecture description provided in this document *provides a common basis for developing implementations of systems of systems that realize the GreenCharge concept*, as outlined by seven scenarios in the GreenCharge proposal. Table 17 lists these scenarios and shows how they are met by the overall use cases depicted in Figure 5 in section 3.2. All scenarios are supported. The functionality needed is identified, structured, formalised and elaborated into detailed use cases (see section 6.1) with detailed descriptions of the functionality needed based on inputs from the GreenCharge pilots (deliverable D2.3, D2.9 and D2.16). The detailed use cases, identified stakeholder concerns, and derived requirements ensure that the system design provided by this reference architecture description can support holistic and relevant solutions for smart and green charging.

Table 17 How the Green Charge Scenarios are met by the overall use cases in section 3.2

	Overall use cases						
Scenarios from the GreenCharge proposal	**Plan and authorise charging**	**Charge EV**	**Manage EV fleet**	**Manage charging**	**Manage energy use and storage**	**Provide roaming**	**Plan and execute other energy demanding activities**
Charge planning and booking	X			X	X	X	
Charging at booked charge station		X		X			
Booking Enforcement		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	X				

This deliverable is an initial version of the GreenCharge reference architecture description. The work was accomplished before the actual implementation of the GreenCharge pilots and before the final decisions on the collection of research data were taken. Thus, there are shortcomings:

- An iterative process with feedback from the implementation work at the pilot sites was not possible, and input on the preferred protocols and interfaces between the system components used at the pilot sites has not been received. Thus, the system information model in 8.1, the interfaces defined in 8.2 and the sequence diagrams in 8.3 are based on theoretical studies and adaptions of existing protocol and interface specifications (provided by project partners and found in existing standards). These specifications in this initial version of the architecture are meant as inspirations for the pilot implementations.
- The input on ongoing standardisation work in not complete. Just the work available as official pre-releases are so far used.
- The specification of the research data in 8.1 is based on preliminary studies and input from the evaluation plans in D5.1 and D6.1 and does not reflect the final plans for data collection.

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11.2 Further work

The GreenCharge reference architecture description will be used as a blueprint when the initial versions of the GreenCharge demonstrators are described in deliverable D4.3. Thus, the work on D4.3 will generate input on the usability of the reference architecture that will guide the further work on the final version of the reference architecture, GreenCharge deliverable D4.2.

The final version of the reference architecture description, GreenCharge deliverable D4.2, will

- Provide improved guidelines on how to use the reference architecture based on lessons learned from the work on D4.3 and the implementation of the demonstrators.
- Provide improved reading guidelines adapted to the needs of specific stakeholders.
- Adapt the reference architecture description to the needs and lessons learned from the implementation of the GreenCharge pilots and the work on D4.3.
- Include an updated version of the information model that specifies all the information that is to be exchanged between the services as well as the research data to be collected.
- Provide the final specifications of the protocols and interfaces based on input from the pilots as well as input from standardisation work.
- Provide updated and more detailed requirements related to the collection of research data.

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

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