SCALE

Use case evaluation report

Project deliverable D3.2

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SCALE Introduction

SCALE (Smart Charging Alignment for Europe) is a three-year Horizon Europe project that explores and tests smart charging solutions for electric vehicles. It aims to advance smart charging and Vehicle-2-Grid (V2G) ecosystems to shape a new energy system wherein the flexibility of EV batteries' is harnessed. The project will test and validate a variety of smart charging and V2X solutions and services in 13 use cases in real-life demonstrations in 7 European contexts: Oslo (NO), Rotterdam/Utrecht (NL), Eindhoven (NL), Toulouse (FR), Greater Munich Area (DE), Budapest/Debrecen (HU) and Gothenburg (SE). Going further, project results, best practices, and lessons learned will be shared across EU cities, regions, and relevant e-mobility stakeholders. SCALE aims to create a system blueprint for user-centric smart charging and V2X for European cities and regions.

SCALE's consortium comprises 29 cutting-edge European e-mobility actors covering the entire smart charging and V2X value chain (equipment and charging manufacturers, flexibility service providers, research and knowledge partners, public authorities, consumer associations, etc.) It is led by ElaadNL, one of the world's leading knowledge and innovation centres in smart charging and charging infrastructure.

List of abbreviations and acronyms

Acronym	Meaning
AC	Alternating Current
AFID	Alternative Fuels Infrastructure Directive
AFIR	Alternative Fuels Infrastructure Regulation
aFRR	Automatic Frequency Restoration Reserve
BEMS	Building Energy Management System
BRP	Balance Responsible Party
BSP	Balancing Service Provider
CCS	Combined Charging System
CEP	Clean Energy for all Europeans Package
CP	Charge Point
CPMS	Charging Point Management System
CPO	Charge Point Operator
DC	Direct Current
DSO	Distribution System Operator
EED	Energy Efficiency Directive
eMIP	eMobility Interoperation Protocol
EM	Energy Manager
EMS	Energy Management System
eMSP	e-Mobility Service Provider
EPBD	Energy Performance of Buildings Directive
ETD	Energy Taxation Directive
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment

FCR	Frequency Containment Reserves
FSP	Flexibility Service Provider
GDPR	General Data Protection Regulation
GRI	Global Reporting Initiative
HEMS	Home Energy Management System
ISP	Imbalance Settlement Period
KPI	Key Performance Indicator
LDV	Light duty vehicle
mFRR	Manual Frequency Restoration Reserve
MWS	Megawatt Charging System
OCHP	Open Clearing House Protocol
OCPI	Open Charge Point Interface protocol
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
OICP	Open InterCharge Protocol
OpenADR	Open Automated Demand Response
PKI	Public Key Infrastructure
PV	Photovoltaic
RED	Renewable Energy Directive
RTO	Research and Technology Organisation
SCALE	Smart Charging Alignment for Europe
SoC	State-of-Charge
TEN-T	Trans-European Transport Network
ToU	Time-of-Use
TSO	Transmission System Operator

VPP	Virtual Power Plant
V1G	Vehicle-One-Grid
V2B	Vehicle-to-Business
V2D	Vehicle-to-Depot
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
V2P	Vehicle-to-Public
V2X	Vehicle-to-Everything

Report executive summary

Keywords

Electric vehicles, smart charging, Vehicle-to-Anything, flexibility markets, interoperability, Use cases, Control topology, System Architecture

Summary

SCALE (Smart Charging Alignment for Europe) is a three-year Horizon Europe project that explores and tests smart charging solutions for electric vehicles. It aims to advance smart charging and Vehicle-2-Grid (V2G) ecosystems to shape a new energy system wherein the flexibility of EV batteries' is harnessed. The project will test and validate a variety of smart charging and V2X solutions and services in 13 use cases in real-life demonstrations in 7 European contexts: Oslo (NO), Rotterdam/Utrecht (NL), Eindhoven (NL), Toulouse (FR), Paris (FR), Greater Munich Area (DE), Budapest/Debrecen (HU) and Gothenburg (SE). Going further, project results, best practices, and lessons learned will be shared across EU cities, regions, and relevant e-mobility stakeholders.

SCALE aims to create a system blueprint for user-centric smart charging and V2X for European cities and regions.

The *Use case evaluation report* (SCALE deliverable 3.2) is the second report of Work Package 3, and builds forth on the earlier SCALE work package 3 deliverable 3.1 Use case setup report (Christiaens et al., 2023). The report evaluates the use cases according to a uniform methodology and extracts overarching conclusions to present on behalf of all use case leaders and SCALE.

Figure 1. Use case locations

Consistent with the D3.1, use case evaluations are done following the methodology introduced in the SCALE *Stakeholder analysis (D1.2)* (Langenhuizen et al., 2022), where Industry Value Chains were introduced. The benefits of organising the smart charging and V2X ecosystem into different industry value chains are to analyse and understand different market models and processes within the ecosystem. The four identified Industry Value Chains are defined as Charging infrastructure, Mobility services, Charging services and Energy services. Besides the industry value chains, the evaluation framework also focuses on the system architecture and underlying control topology and communication protocols applied in the use cases.

The individual use case results presented in the report display a strong diversity of services being tested in line with this wide scope. This report engages a broad variety of topics and draws parallels between use cases where possible. To display the full overview of the use cases' realised scope in detail, the full report also includes five annexes with comprehensive overviews on use case execution scope details. With respect to the overarching use case evaluation findings, in the full report the results have been organised into the following eight relevant topics. These findings are the results of a physical workshop and follow up sessions with the SCALE partners.

Smart charging and V2X unlocks flexibility	The use cases have demonstrated significant progress in smart charging (V1G) and Vehicle-to-Everything (V2X) solutions, showing potential for grid balancing and enhanced energy system flexibility. The adoption of ISO 15118-2/20 and OCPP 2.x standards can further improve these capabilities, offering increased flexibility and grid optimization through advanced smart charging and V2X infrastructure.
Differences between AC & DC charging	SCALE aims to understand how different hardware components, especially charge points, can enhance smart charging and V2X capabilities, despite challenges in rolling out the ISO 15118 protocol, compliance with grid codes and availability of V2X chargers. DC charging faces fewer barriers and benefits from established high level communication standards, while AC charging, despite current limitations, offers long-term flexibility and grid management potential. Both AC and DC charging methods have distinct advantages and can coexist, fulfilling complementary roles in the different use cases for smart charging and V2X solutions.
Harmonisation of ecosystem	The implementation of ISO15118-20 and OCPP2.x standards in EVs and charge points is still in its early stages, with existing implementations mostly in pilot phases or limited setups. Achieving broader adoption and seamless integration of these standards requires further implementation across the ecosystem, extensive interoperability testing, and harmonization with the energy domain to fully realize the flexibility potential of EVs and optimize grid stability. Further harmonisation of these standards in the ecosystem would reduce the dependency on system integrators and enable the faster scaling up.
Access to data	Access to data is crucial for enabling smarter charging and increasing flexibility in energy services, as highlighted in SCALE reports D3.2 and D2.2. However, challenges such as GDPR regulations and the need for cooperation among stakeholders can limit data accessibility and integration in real-world applications. Moreover, incentives for certain stakeholders are lacking and hinder cooperation.
All stakeholders are essential	Effective implementation and scaling of smart charging and V2X solutions require active participation from all stakeholders in the ecosystem. Notably, EV and charge point manufacturers, as well as grid operators play a central role in the ecosystem. Besides activation of these stakeholders, challenges faced by manufacturers such as grid code compliance for V2X, and the need for better harmonisation and interoperability should also be accounted for in the run up to mass deployment.

Access to market mechanisms	Access to advanced market mechanisms contributes to optimizing the economic potential of smart charging and V2X technologies, enabling EVs to participate effectively in energy services and capture financial benefits. These mechanisms must be adaptable to local regulations and requirements, addressing the specific needs of grid operators or Balance Responsible Parties (BRPs) and highlighting the significant role of aggregators in unlocking profitability.
Consumer awareness	Consumer participation is crucial for the adoption of smart charging and V2X solutions, however concerns about battery degradation and a lack of awareness on the benefits and impacts of bidirectional charging need to be addressed for greater uptake.
Regulatory framework	The current regulatory framework presents challenges for the mass deployment of smart charging and V2X technologies, with key obstacles including grid code regulations, double taxation and inconsistent feed-in tariffs across EU member states. Addressing these issues through regulatory updates, harmonization, and opening markets for flexibility services is essential to unlocking the full potential and profitability of these technologies.

For more detail on the methodological framework, individual use cases evaluations, and the conclusions in full, we refer to the complete report in which these are provided.

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Purpose of the deliverable

The *Use case evaluation report* (SCALE deliverable 3.2) is the second report of Work Package 3, led by FIER Sustainable Mobility. It builds on the earlier SCALE work package 3 *Use case setup report* (D1.5) (Christiaens et al., 2023), as well the work done in both *Multi-actor Smart Charging & V2X System Architecture* (D1.4) (Geerts et al., 2024) and *Analysis of hard- and software requirements (D1.5)* (Meersmans et al., 2023). The report evaluates the use cases underpinning SCALE according to a uniform methodology and extracts overarching conclusions to present on behalf of all use case leaders and SCALE.

Consistent with the D3.1, use case evaluations are done following the methodology introduced in the SCALE *Stakeholder analysis (D1.2)* (Langenhuizen et al., 2022), where Industry Value Chains were introduced. For each use case, the implemented charging concepts and energy services are evaluated and detailed consideration is given to achieved objectives and KPI's so as to identify validated approaches for accelerating the uptake of smart charging and Vehicle-2-Grid (V2G) ecosystems.

1 Introduction

SCALE aims to advance EV charging technology and facilitate the mass market uptake of smart charging and Vehicle-to-Everything (V2X) technology. To do this, 13 use cases are executed over 4 innovation clusters: Vehicle-to-Home, Vehicle-to-Business, Vehicle-to-Depot, and Vehicle-to-Public.

In all 4 innovation clusters, smart charging and V2X technologies will be tested. This *Use case evaluation report* (SCALE deliverable 3.2) provides a comprehensive evaluation and use case specific assessments on the achievement of the use cases' objectives and prospective upscaling potential for operations based on achieved KPIs. Furthermore, it also provides more general use case derived findings in relation to setting up and executing the innovations on smart- and bidirectional. This use case evaluation report builds forth on the earlier SCALE work package 3 deliverable 3.1 Use case setup report (Christiaens et al., 2023).

The report is composed of 3 chapters, with chapter 1 presenting the overall context of the project, and the applied methodology for use case evaluations. In chapter 1 the evaluation process of the evaluation as well as the methodological framework are described.

Chapter 2 focuses on the individual use cases, providing a summary of executed activities, specifics on the scope of use case execution as well as targeted evaluations. Regarding system architecture, the different control topologies and communication protocols applied in the use case are also explained here. Additionally, learnings on the use case setup process are covered as part of the evaluation process. Finally, detailed consideration is given to how objectives and KPI's were achieved as well to which results could speed up the uptake of smart charging and Vehicle-2-Grid (V2G) ecosystems.

Chapter 3 concludes with the main findings of the SCALE use cases and assesses avenues to likely to accelerate faster mass adoption and deployment of smart charging and V2X.

SCALE way of working

In SCALE, the process of setting up the use cases was spearheaded by the local use case leaders (see figure 1.) who were in turn cooperating with the other SCALE partners who are providing their expertise, services and hardware. Within SCALE, these activities were carried out in work package 3, led by FIER Sustainable Mobility. The cooperation between partners within SCALE is regular and sustained over the project: a necessary approach as most use cases are dependent on many different SCALE partners and other SCALE work packages.

Figure 1. Use case leaders and work package leader logos

To support this process, monthly meetings, chaired by FIER, were attended by all use case leaders. In these meetings, the progress of the set-ups, encountered bottlenecks, available solutions, and other relevant aspects were discussed. With work package overarching activities being addressed in follow-up meetings as needed. Besides the WP3 structure, there were many bilateral exchanges among the use case leaders and other SCALE partners to further support the development of individual use cases and ensure that all objectives were attained.

Use case evaluation report approach and method

The *Use case evaluation report* was prepared by FIER Sustainable Mobility and the use case leaders. The core information was provided by the use case leaders and consolidated by FIER into this report. Starting from harmonised templates, detailed input from the use case leaders was collected. In turn, this information has been carefully collected and collated in this report. Furthermore, as final exercise, a lively workshop discussion was held during our annual physical consortium meeting (Budapest, November 2024), with the information gathered being refined in additional alignment meetings. This process allowed FIER to draw up key combined learnings and conclusions to present on behalf of all use case leaders and SCALE.

1.1 Road to deployment of use cases

Since the inception of SCALE in 2022, each use case followed three phases:

1. Preparation & set-up through the procurement and installation/adaptation of required elements including appropriate vehicles, smart charging infrastructure, V2X hard and software, etc.
2. Execution and monitoring
3. Quantitative and qualitative data gathering

Due to the innovative character of this project, phase 1 also included many activities defining, refining and, at times, re-defining the executable scope as a function of achievable ambitions influenced by a range of internal and external factors. The full results of phase 1 can be consulted in the SCALE Project deliverable D3.1 (Christiaens et al., 2023).

Having now concluded phase 2, and with most use cases nearing completion of phase 3, the scope of the execution and monitoring activities which will feed the final phase have now been conclusively defined. In hindsight, it is worth noting that the innovative and experimental nature of the activities have often provided new insights and challenges along the way, requiring an iterative approach to certain activities. In closing, as the final phase comes to an end, the conclusion of the methods, recommendations and lessons learnt which are of most value in driving for mass adoption can now be considered.

1.2 Evaluation framework

Building on the approach in SCALE D3.1, any updates to use case's scope and evaluations are done following the methodology introduced in the SCALE *Stakeholder analysis (D1.2)* (Langenhuizen et al., 2022), where Industry Value Chains were introduced. The four identified industry value chains are defined as Charging infrastructure, Mobility services, Charging services and Energy services as visualised in Figure 2. The benefits of organising the smart charging and V2X ecosystem into different industry value chains are to analyse and understand different market models and processes within the ecosystem.

In the following sections, a description is included per industry value chain, followed by a description of how this is included in the specific scope of each SCALE use case. By using the industry value chains to describe the use cases being evaluated, a comprehensive picture can be given of them.

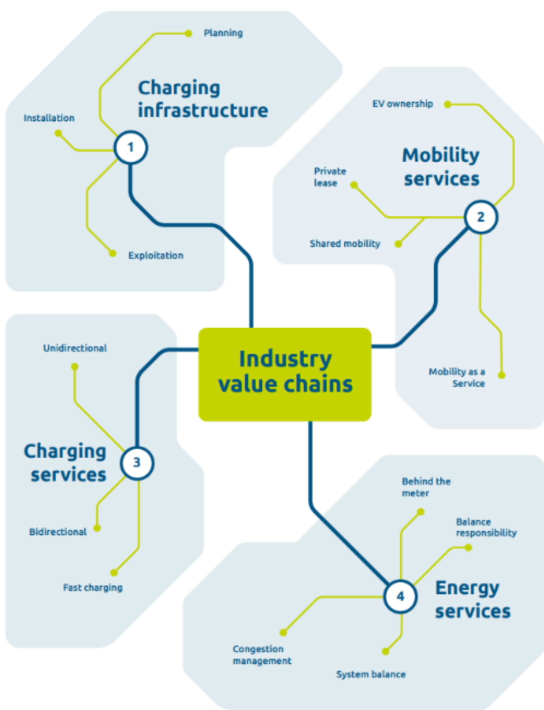


Figure 2. Industry value chain

1.2.1 Charging infrastructure

The charging infrastructure industry value chain is separated into three phases: 1) planning, 2) installation, and 3) exploitation. The below describes the three phases of charging infrastructure in more detail.

Planning

The planning of charging infrastructure is a difficult process as the uptake of EVs is dependent on the presence of sufficiently dense charging infrastructure network. What's more, exploiting a profitable charging infrastructure is also dependent on the sufficient uptake of EVs. In short, this is the well-known chicken-and-egg problem of electro-mobility (Arias-Gaviria & al., 2021).

The SCALE use cases are, in certain occasions, building on existing or already planned charging infrastructure initiatives, which initially did not include smart charging and/or V2X charging while they were planned or installed. Even though the charging infrastructure itself has already been installed, and in some use cases is already operational, in SCALE these use cases will expand on the existing situation with an additional layer with software and hardware updates to implement innovative smart charging and/or V2X solutions throughout the process. This implies that for certain use cases there are dependencies on these existing, or committed and planned, initiatives.

Installation

The installation phase of the charging infrastructure deals with the actual placement of the charging equipment. Same as with the planning phase, many of the SCALE use cases are being carried out at existing sites. In these situations, the installation phase may refer to the phase where reworks on the existing hardware or software upgrades on the product level are implemented. Aside from the fact that installation work is getting more expensive and delivery times for materials are relatively long, there have been no unexpected results during the installation phase.

Exploitation

In the exploitation phase the charging infrastructure is in operation and being used by the end users. At this stage, results and data that are being gathered from the operational use cases.

1.2.2 Mobility services

Mobility can be offered to end users in different ways. As already written in the *Stakeholder analysis* of SCALE *(D1.2)* (Langenhuizen et al., 2022), the paradigm is shifting from only ownership of vehicles to other mobility services. In SCALE there are different varieties of mobility services in the use cases. The mobility services used in SCALE are private cars, shared cars (business-to-business and business-to-consumer, and leasing cars (company cars). One of the SCALE goals is to better understand the impact of different mobility services on the smart charging and V2X potential, e.g. the intentions of the explicit placement of shared cars in some use cases is that these are always connected to a charger when not in use, they are owned by a central professional organisation instead of by many individuals, and that their usage pattern is known from the reservation system. It is foreseen that these factors strongly enlarge the potential per car and cause car sharing systems to have an important position in scaling-up of V2X operation of e-cars. The same is true, to a lesser degree, for leased cars.

Most of the innovation in SCALE does not revolve around mobility services; the focus is on smart charging and V2X charging. That being said, V2X services can only take off, when all stakeholders from the entire ecosystem are participating. When, for example, looking at the flexibility that EVs can offer to the electricity grid, it is important that as many vehicles as possible are participating. One vehicle offers only a small flexibility potential. For this reason, it is important to understand all different potential stakeholders and test smart charging and V2X solutions in multiple mobility services.

1.2.3 Charging services

With the development of smart charging and V2X services within SCALE, the impact that charging of EVs has on the electricity grid is drastically reduced. This is done by implementing energy services; these are described in §1.3.4. Which energy services can be offered is determined by a number of factors, one of which is the charging service. As described in the SCALE *Stakeholder analysis (D1.2)* (Langenhuizen et al., 2022), 3 charging services can be determined: 1) unidirectional charging, 2) bidirectional charging, and 3) instant fast charging. All 3 charging services were deployed in the SCALE use cases.

Unidirectional charging

Unidirectional charging means that the power is only going from the grid to the vehicle, this is the most well-known charging service today. Most of the currently available charging services are unidirectional. However, within this charging service, there is an important distinction to be made, between *smart charging* and *uncontrolled charging*. Uncontrolled charging stations can only deliver full power, at the request of the EV, and cannot be managed. With charging stations that have smart charging functionalities the power level can be controlled. This way, EV charging can become part of the solution instead of the problem, e.g. EV charging can be initiated or maximised when there is an abundance of renewable energy and can be stopped or reduced when there is high energy demand or there is congestion on the electricity grid. This way the charging sessions are contributing to a more stable electricity grid.

Within smart charging, there are different levels of control. The first, and often already available manner of smart charging, is charging stations controlled being reduced in power when the maximum power on the grid connection is reached. This is a very effective way of smart charging, but it doesn't take any other factors into account than the measurements at the grid connection. Within SCALE, the use cases go further than this: additional data sources are used to manage and optimise the charging sessions. More on this will be described in the paragraph §1.2.4 on the Energy services.

Bidirectional charging

Bidirectional charging, as the term implies, means that power can go into the car, but also from the car back to other (non-mobility) related use. In this situation, the battery of the vehicle is being used to store energy that can be used at a later moment. The energy can flow back to several destinations, in Vehicle-to-Home (V2H), Vehicle-to-Depot (V2D), Vehicle-to-Business (V2B), or Vehicle-to-Grid (V2G). We see that many of the Energy Services that are described under §1.2.4 can be done both uni- and bidirectionally, where the latter has the potential to create higher added value and minimise the need for grid reinforcements.

Instant fast charging

The third and last charging service is instant fast charging. The big difference compared to unidirectional charging and bidirectional charging is that with instant fast charging the key priority is to charge with the highest possible amount of energy in the shortest possible timeframe. Unlike the other charging services, instant fast charging can only deliver a satisfactory service when charging at high power. When someone is charging at his or her destination, it often doesn't matter if the vehicle is fully charged two hours before departure or two minutes before departure. This means that there is room to adjust the charging profile. With instant fast charging, the charging profile can be adjusted to a lesser extent. Although there are limitations to the smart charging which can be applied to instant fast charging, there is also still a lot of potential for gains. The planned roll out of a large network of instant fast charging locations alongside the highway in Europe's trans-**European** transport network (TEN-T) is expected to require huge investment in electricity grid. This can be reduced by implementing smart solutions, e.g. in combination with local energy storage, to reduce the impact of these charging locations on the grid.

1.2.4 Energy services

In the combination of mobility and charging services, different energy services can be provided using the batteries in electric vehicles in a smart way. In SCALE, Energy services are divided into 4 categories: 1) local behind-the-meter optimization, 2) balance responsibility, 3) system balance, and 4) congestion management. Per category, different energy services can be identified and in this section of the report they are introduced.

Most energy services can make use of unidirectional or bidirectional charging services. The main difference is that with energy services going via bidirectional charging the potential that can be offered to the grid is larger than with unidirectional charging. For instance, executing the energy service *Optimize photovoltaic (PV) self-consumption* aims to increase the use of generated power from a PV installation. With unidirectional charging, you can charge the EV when the PV installation is producing power and stop or reduce charging if there is no PV power generation. In this way, you are executing this energy service because you are optimizing the PV consumption. Unfortunately, when the battery is full, you can no longer execute the energy service. When using bidirectional charging with the same energy service, the EV can offer more value. In this situation, you can charge the EV when the PV installation is generating power whilst in turn providing power to a home or other buildings whilst there is no PV power generation (for instance, at night), and then charge the EV again the next day.

Local behind-the-meter optimization

Local behind-the-meter optimization is, as the name suggests, done without power going back to the grid. All the optimization, whether it is unidirectional (smart charging) or bidirectional (V2X), is taking place behind the meter at a home, office building, or other location. The optimisation is typically controlled by the site owner.

Table 1. Local behind the meter optimization

Energy service	**Description**
Increase self-consumption of on-site renewable energy	When a consumer has rooftop solar with a feed-in tariff different from the supply tariff, value can be created by maximizing the consumption of locally generated solar.
Reduce demand charges	When a consumer is exposed to capacity related charges (€/kW over a period), such demand charges can be reduced by applying peak shaving.
Time-of-Use shifting	When a consumer is subject to time varying electricity prices in the form of static ToU, dynamic pricing, critical peak pricing, etc., value can be generated by avoiding exposure to high prices of behind-the meter consumption.
Provide back-up power	When a grid outage is detected, the vehicle can provide back-up power to the household.

Balance responsibility

On the electricity grid, supply and demand need to be balanced: the same amount of energy needs to be generated as the energy that is used. The responsibility for matching supply and demand lies with the Balance Responsibility Party (BRP), which is, on many occasions, the energy supplier. Underneath, there are energy services associated with balance responsibility. With a single car being typically too small of an asset to provide these services, aggregation of these assets is needed for them to participate as BRP.

Table 2. Balance responsibility

Energy service	Description
Wholesale market price arbitrage	Capacity can be managed as a sub pool within the BRP's portfolio and gain additional revenues can be charged at low price moments and discharged at high price moments (BRP provides market access).
Intraday portfolio optimization	For BRPs with a large part of renewable energy in their portfolio, the flexibility of aggregated capacity within this portfolio of grid connections can be used to compensate for the forecast errors and the imbalances in this portfolio.

System balance

For a stable electricity grid, the system balance is important. To achieve system balance, the electricity grid needs to maintain a stable frequency of 50 hertz. A Balance Service Provider (BSP) provides this balancing service to the Transmission System Operator (TSO). EVs can be an example of assets that are used to provide the service. With smart charging electric vehicles can only be used as a demand asset, it can only take power from the grid. With V2G, the electric vehicles can also be used as supplying assets. With a single car being typically too small of an asset to provide these services, aggregation of these assets is needed. Underneath are the energy services associated with system balance.

Table 3. System balance

Energy service	Description
FCR	Frequency Containment Reserve (FCR). Aggregated capacity offered by a BSP can be called upon by the TSO to restore imbalances in a Local Frequency Control Area.
aFRR	Automatic Frequency Restoration Reserve (aFRR). Aggregated capacity offered by a BSP can be called upon by the TSO to restore imbalances in a Local Frequency Control Area. Required activation is slower than FCR.
mFRR	Manual Frequency Restoration Reserve (mFRR). Aggregated capacity offered by a BSP can be called upon manually by the TSO to restore imbalances in a Local Frequency Control Area
Strategic reserves (adequacy)	Aggregated discharging ability could be used as strategic reserves and provide an alternative for thermal power plants or industrial demand response capacity to improve the adequacy of the system

Congestion management

The last of the 4 categories in which energy services are divided is congestion management. As described in the SCALE *Stakeholder analysis (D1.2)* (Langenhuizen et al., 2022), congestion management is typically needed on occasions when certain parts of the distribution system risk getting overloaded or congested. Congestion management energy services can be aimed at preventing and resolving congestion. Below are the energy services related to congestion management.

Table 4. Congestion management

Energy service	Description
Long-term Flexibility agreement	V1G/V2X can provide a non-wire alternative and expand the lifetime of the existing Distribution System Operator (DSO) infrastructure through long term congestion management contracts.
Short term congestion management (D-1)	When congestion in the local grid is expected in D-1, V1G/V2X can provide congestion management services in short term congestion management markets through contracted bids.
Operational congestion management (near real-time)	When congestion is detected in near real-time, congestion management services can be activated from V1G/V2X through non-contracted bids.
Power Quality control	When the operational limits (voltage, phase imbalance, ...) of the local electricity grid are reached, rapidly discharging or charging electric vehicles could help restore the local grid within its normal operating boundaries.

1.2.5 System architecture

Beyond the building blocks introduced in the industry value chain, the evaluation framework also builds forth on the work done in task 1.4 on the system architecture. SCALE tested several applications of smart charging and V2X charging solutions. The goal of the different solutions, over different mobility services, charging services, and energy services is to ensure that electric vehicles are not a strain on the grid, but rather can support the grid and reduce the need for grid reinforcement. To use EV charging sessions to reduce the grid impact, EVs and charge points need to be able to work together as well as with many other systems that make up the smart charging and V2X ecosystem. Also, these subsystems of the ecosystem need to be interoperable in order to be ready for upscaling for mass deployment. Herein lies a great challenge: the system architectures of these ecosystems are not yet fully developed and aligned among the different stakeholders in the ecosystem. For the complete overview of the SCALE protocols and standards we refer to the SCALE *Analysis of hard- and software requirements (D1.5)* (Meersmans et al., 2023) To have the ecosystem fully cooperating and communicating, a sound system architecture is necessary. This consists of all the actors involved, the roles of these actors, the communication protocols used, and the energy services provided. There is no one-size-fits all system architecture as every situation can have key differences leading to other choices in the system architecture. However, there are certain important aspects which are universal, or at least recommended.

In the setup and execution of the use cases the system architecture has been a central focus and further elaborated on in SCALE deliverable 1.4 *Smart charging and V2X system architecture* (Geerts et al., 2024).
For each of the use cases the system architecture is provided in the D3.1 and updates on the control topology and protocols is provided in chapter 2 of this report.

Control topology

The control topology means the way of controlling a charging session and which actor is doing the actual controlling of the charging session. There are three control topologies that can be distinguished: the car manufacturer (OEM), the Charge Point Operator (CPO), or the Energy Manager (EM). Each of these control topologies has a control system which is able to control the asset. In Chapter 2 it will be indicated per use case which control topology is used. There is no good or bad choice, but the choice for a control topology does have implications for the rest of the system architecture and data requirements. For example, the actors that need to be involved and the communication protocols that can be used.

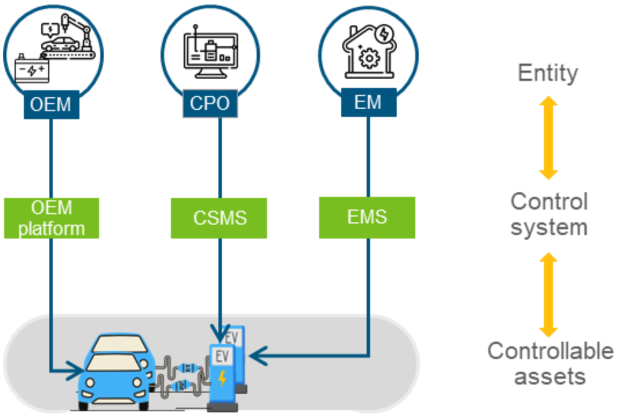


Figure 3. Control topologies

Communication protocols

In *chapter 3 & 4* of the SCALE *Analysis of hard- and software requirements (D1.5)* (Meersmans et al., 2023) a very detailed description of all the necessary hard- and software requirements for the electric vehicle, the charging station, and the Charge Point Operator (CPO) is given. This is very relevant and necessary input to the work done on the system architecture. Important protocols to be included in the system architecture are Open Charge Point Protocol (OCPP) and Open Charge Point Interface (OCPI). The latest or soon to be released protocol versions of OCPP & OCPI allow for most desired outcomes to be achieved by a V2X ecosystem. With regards to EV-

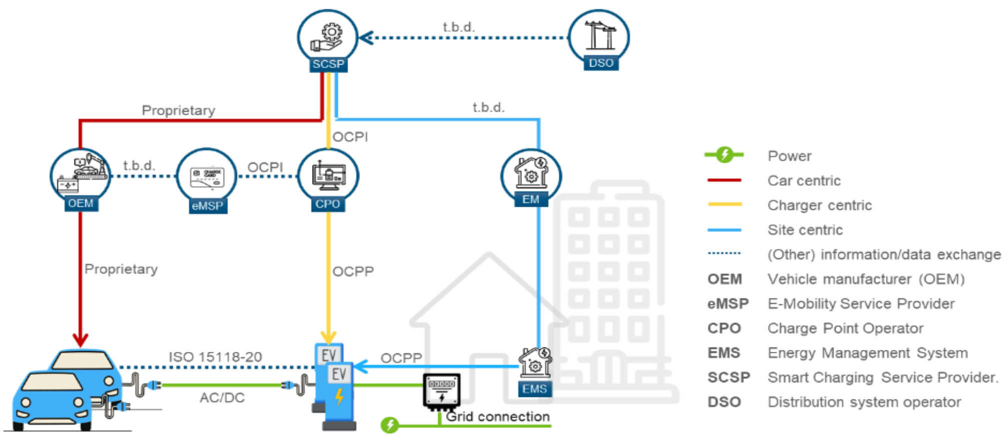


Figure 4. Example architecture on communication protocols

Charging Station communication, the current dominant protocol for both AC charging is IEC 61851.

This protocol is not considered future proof due to several reasons such as lack of support for bidirectional charging and an inability to exchange information between the EV and charging station for smart charging purposes such as present State-of-Charge (SoC) of the EV battery. The bidirectional communication capabilities that ISO 15118-20 offers in addition to IEC 61851 would close most of the gaps related to the desired system outcome for the communication between the EV and the charging station.

Figure 4 shows an example of a representation of the communication protocols as part of the system architecture. This system architecture is merely a representation of the potential actors in the system architecture of a use case with recommended communication protocols. Per use case, the system architecture will differ highly. This is not the final system architecture; this is just an example. In the use case description in Chapter 2 these will be specified further. Use case evaluation process

1.2.6 Process on gathering results

In order to collect and compile uniform information on the use cases, a multi-step process was required to guide the large group of stakeholders represented, primarily, by the uses case leaders. As touched upon in chapter 1.2 regarding the evaluation areas, standardised input formats were created and shared with use case leaders for completion. What's more, physical and online workshops were organised around these requirements to guarantee quality and consistency across all use cases as well as facilitating knowledge sharing.

In summary the tools utilised were as follows:

- A uniform template to provide updated use case context in the broadest sense and present high level goals
- A detailed and use-case specific Excel sheet to report on unique objectives and KPIs and evaluate all relevant components contributing to use-case success
- An Excel based 'use case matrix of realised scope' designed to capture detailed technical scopes, engaged industry value chains and system architecture of all use cases in one wholistic overview

1.2.7 Individual use case reporting structure

With an aim to providing harmonised evaluations, the individual use case evaluations all follow an equal format composed of a contextual section and an evaluation section. The individual use case evaluations in chapter 2 start with the updated context, description and goals of the use case so as to understand the motivation behind each use case. At the same time, this section provide a practical understanding of the relevant service offering and/or stakeholder challenges being addressed. The evaluation process continues with a focus on broader pilot objectives and targeted KPIs related to the upscaling potential as outlined in the project ambitions.

The second part of the process focus on cataloguing reflections around the scope of the use cases; the type of charging services, relevant energy management services and various aspects of system architectures which have introduced in the evaluation framework. In closing, use case leaders reflect on the overall evaluation of pilot results.

2 Individual use case evaluation

In this chapter we will provide specific details on the evaluation of each of the SCALE use case, grouped per innovation cluster. SCALE has identified four Innovation Clusters (based on sites/ specific user groups) for which smart charging and V2X is either already playing a significant role or will become a necessity in the next years. The four Innovation Clusters are: A: Home, B: Business / office, C: Light- and heavy duty, D: Public). Worth noting, use case 00 (WDS) is placed in a separate review category as it overarches the innovation clusters with its range of activities.

As SCALE aims to demonstrate a variety of smart charging and V2X solutions and services in 13 use cases in real-life demonstrations structured the evaluation also focuses on the relation to these innovation clusters. Figure 5 provides an overview of the various locations where the use cases are situated.

Figure 5. Use case locations

2.1 Innovation cluster A: Smart home charging

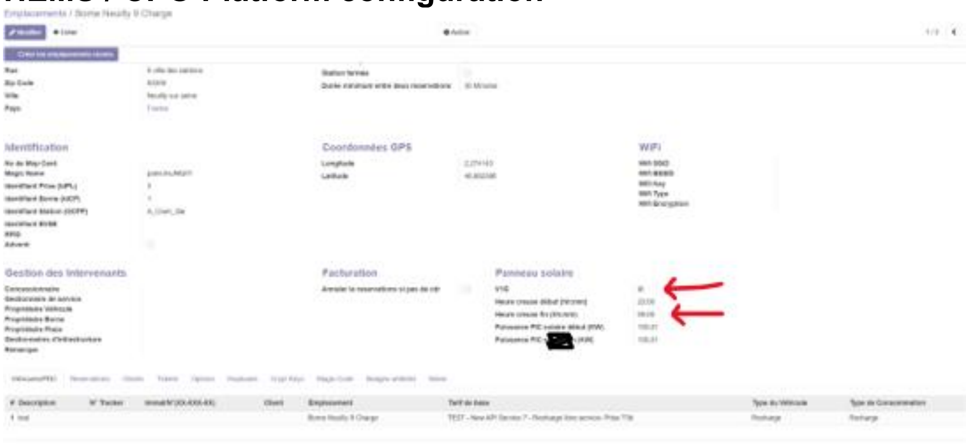
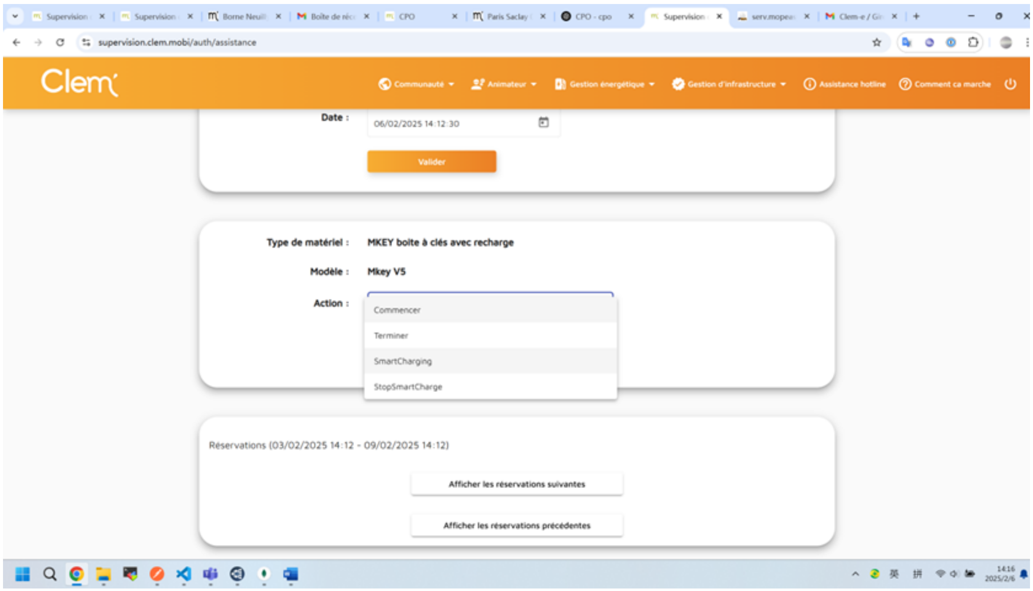
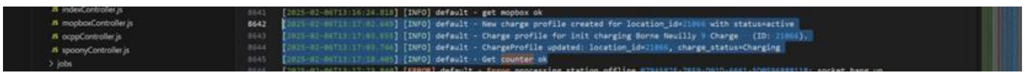
In Smart home innovation cluster, charging of EVs takes place in homes. Therefore, offering important potential for smart charging and V2X functionalities. Utilizing smart charging and V2X can, in this Innovation Cluster, increase the uptake of EVs (through cost benefits and ease of use), as well as increasing the utilization of locally produced renewable energy (e.g. through self-consumption of the generated solar power) thus lowering grid-dependency. That being said, the highest focus was reducing costs (both infrastructures plus operational costs and energy costs) and creating a high quality user experience to ensure high participation throughout society.

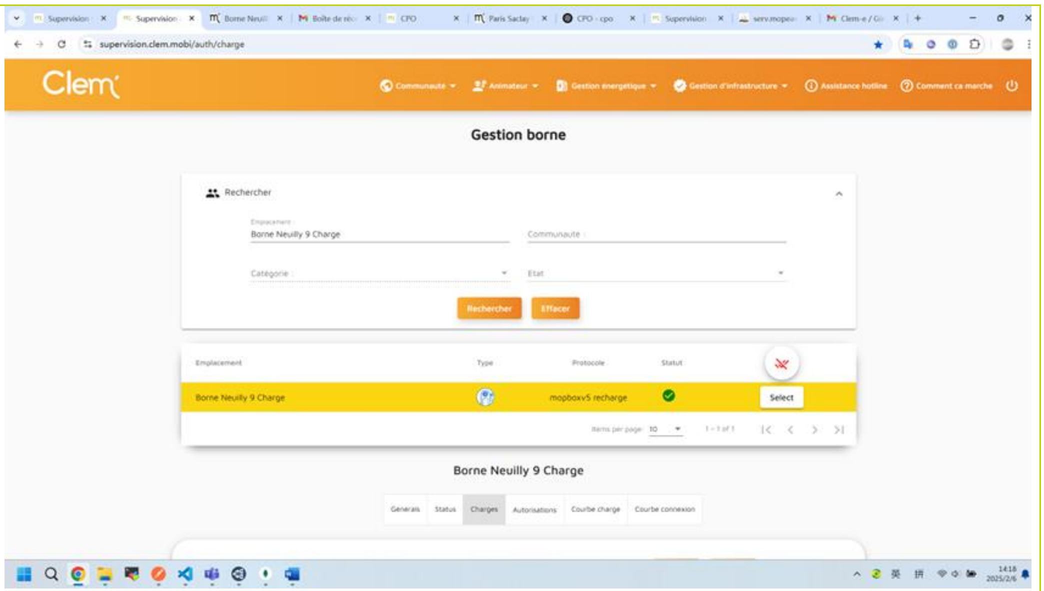
2.1.1 A1.1: Greater Paris with Clem', Enedis, Trialog and Renault/Ampere - Vedecom, EDF R&D - Smart charging & V2X concept for site self-consumption in single family housing

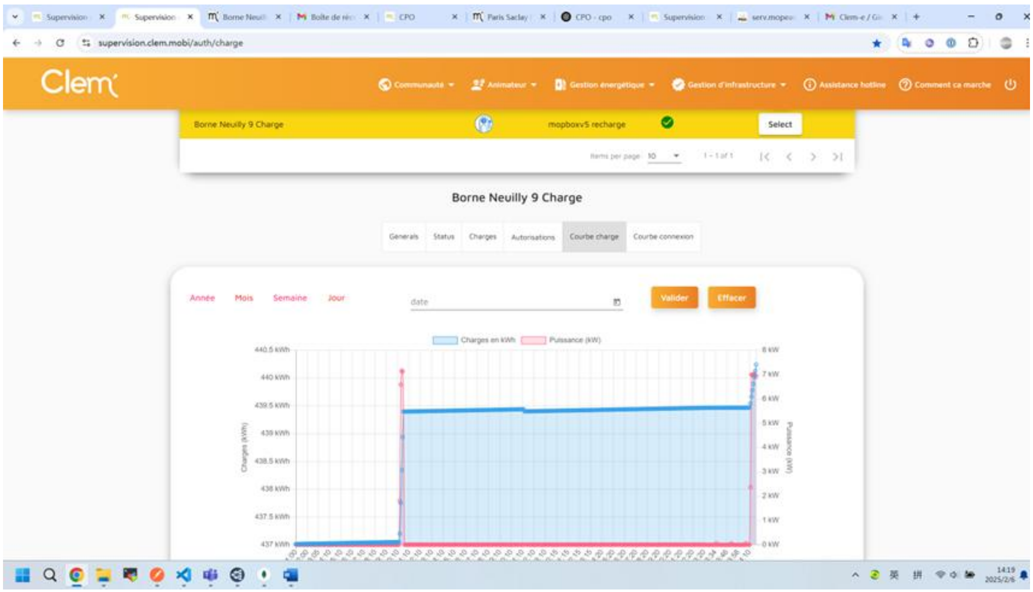
Use case lead	**CLEM**
Use case context	1. Validate the dynamic behaviour of an OCPP 2.1 (Open Charge Point Protocol) system The objective is to validate the system's dynamic response to real electricity consumption data observed in France, as published by RTE 2. Assess the impact of V1G smart charging on a residential building The study focuses on how load shifting—by temporarily reducing or pausing vehicle charging—can optimize building self-consumption and align with peak, off-peak, and upcoming ultra off-peak periods, can reduce the costs by optimizing self-consumption and flexibility and reducing the amount of surplus energy reinjected into the grid at an increasingly lower tariff 3. Explore V2X, V2H, and V2G scenarios through a multi-actor independent set up The tests involve an ecosystem composed of one CPO, one AC V2G charging station manufacturer, one electric vehicle OEM with AC V2G compatibility, and one grid operator, aiming to evaluate interoperability and flexibility in distributed energy systems
Use case description	HOME SUB-METERED INSTALLATION 7kW AC Charging point V1G 7KW AC Charging Point V2G – 4kWc Solar Panel production – 12 kW grid subscription through a Linky Context A 7kW AC charging point is connected under a sub-metering setup within a mixed-use house/office equipped with a Linky smart meter, additional smart meters on the residential zone, the office zone, and on the solar panels. The charging station operates under OCPP 1.6, and the platform is also OCPP 2.1 ready (Scale WP2). A direct connection is established between the Linky meter and the « dry contact » of the charging point. The HEMS smart meters communicate via MQTT and the charging station data is transmitted via OCPP to a all to the all in one energy supervision platform (CPO+HEMS) :"supevision.clem.mobi"

	A first algorithm processes all available data and configuration parameters (assumptions). On top of it, a second algorithm processes cost-saving results The solution is ready to welcome an OCPP2.1 CPO platform, a V2G charging station, anan EV V2G AC ready,, and to be connected to the grid through a DSO, all independent stakeholders.
Use case goal	• Validate AC bidirectional charging as an affordable solution for V2H. • Integrate an EV in a residential energy system using open standards. • Optimize costs and user energy savings. • Reduce peak loads and grid interaction.

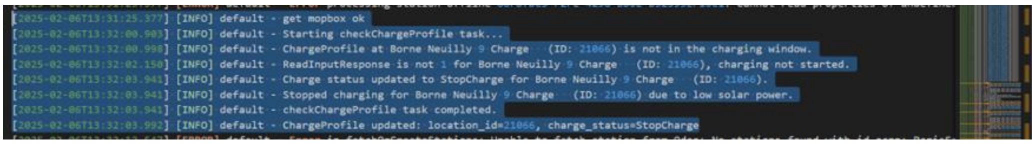
Use case scope The solution includes an OCPP 2.1-ready V2G platform, an an AC V2G-certified station, and configurable house parameters (HP/HC tariffs, solar size, charging power, discharge limits). Users can control smart charging modes and supervisors can respond to Ecowatt peak-reduction signals

Evaluation pilot objectives	
Objective	USE THE SMART METER (LINKY) FOR HP/HC CONFIGURATION
Evaluation	**HEMS / CPO Platform configuration**  **User action:** Start charging session with the “Smart Charging” option enabled.  **Algorithm feedback:** Smart Charging status confirmed as *active*.  **Result:** On the supervision interface, the location and session can be monitored, and the **charging curve** can be viewed.

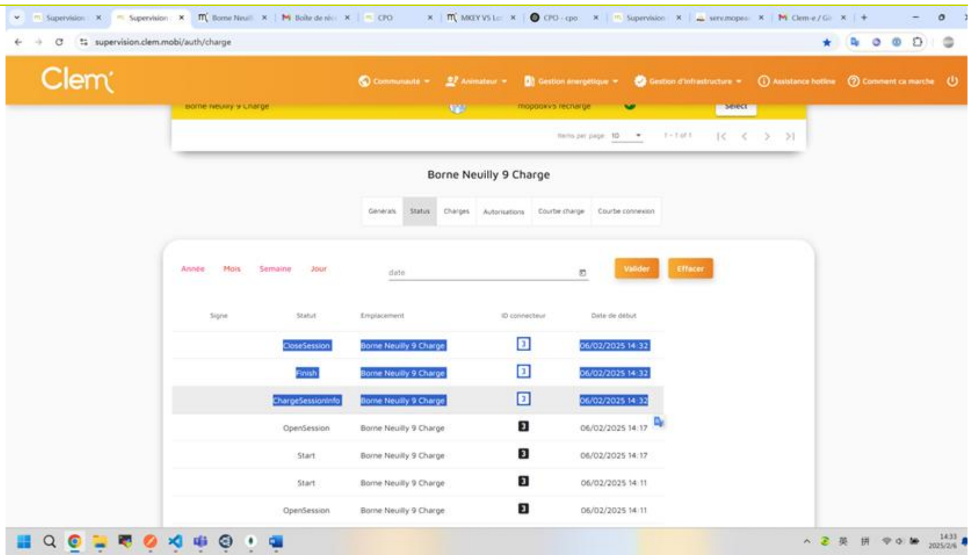




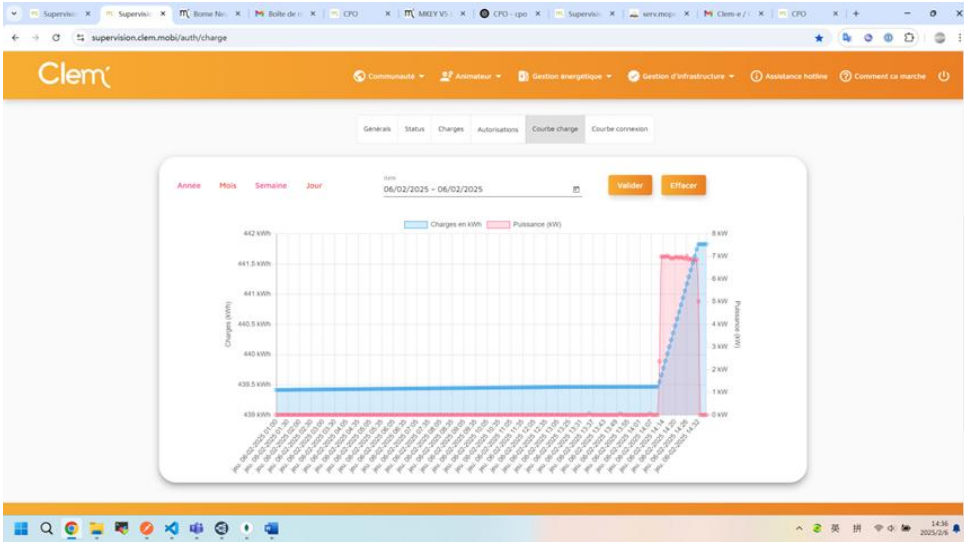
A **7kW charging session** is initiated.
However, as the current time falls within the **Peak period**, charging is automatically **suspended**.



The **supervisor** can monitor the charging status in real time on the platform.

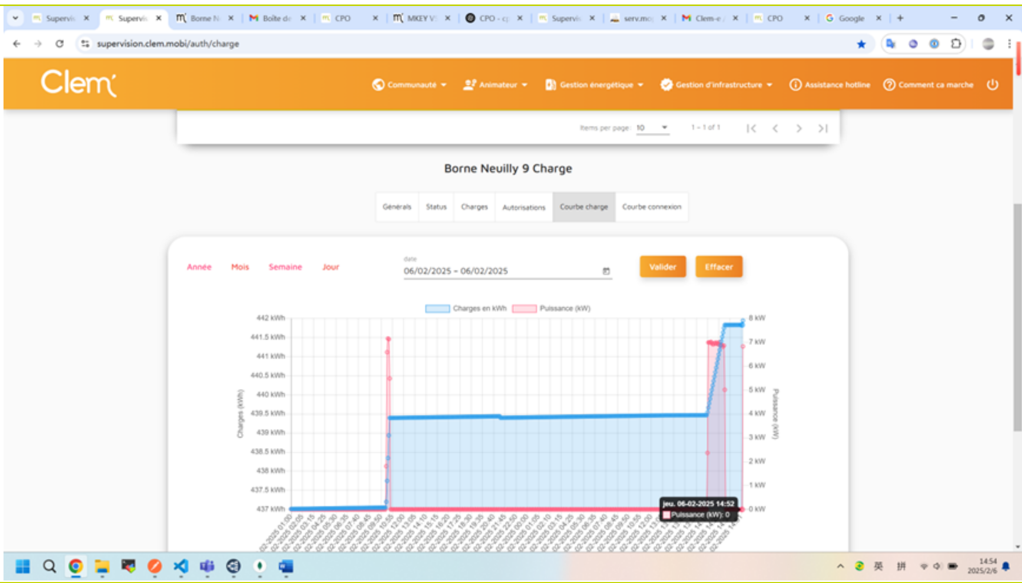
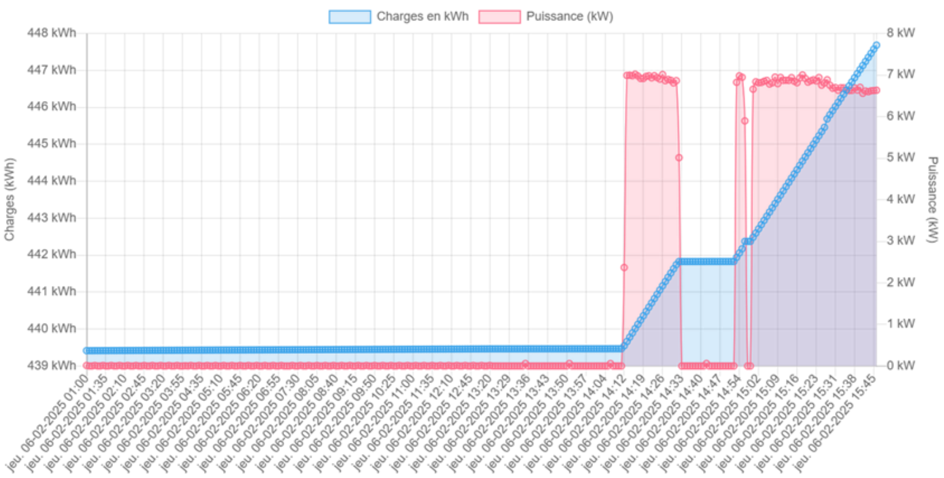


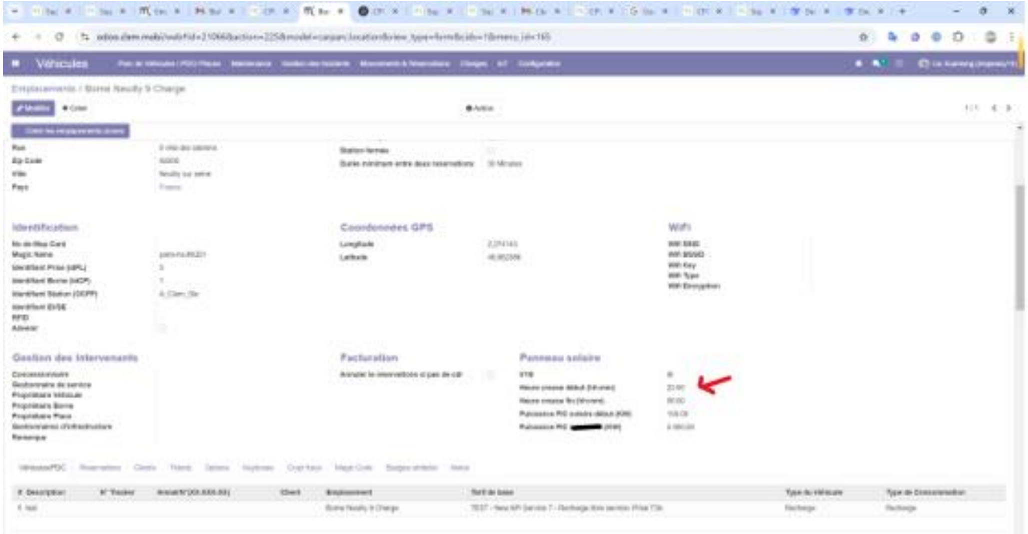
The **charging curve** clearly shows the suspension event.

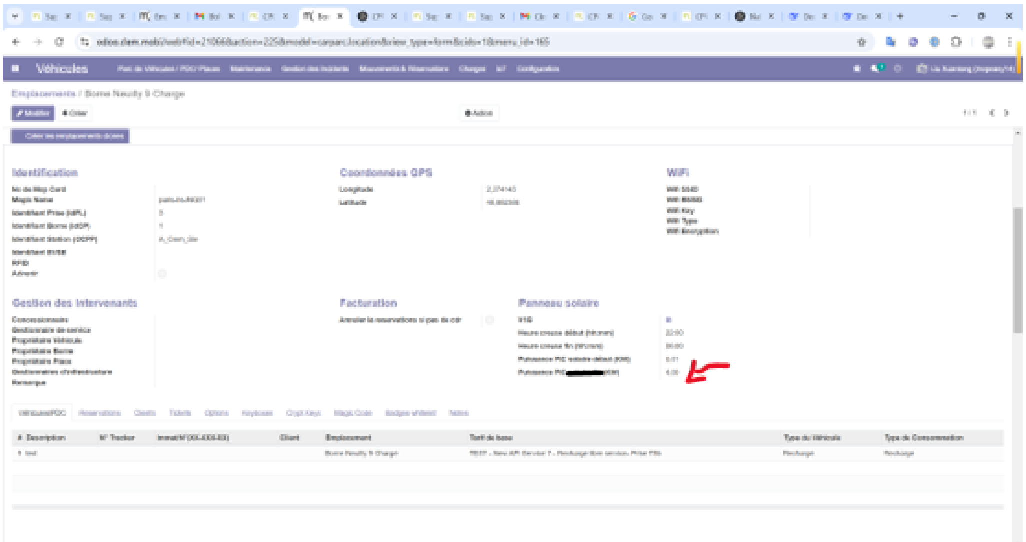
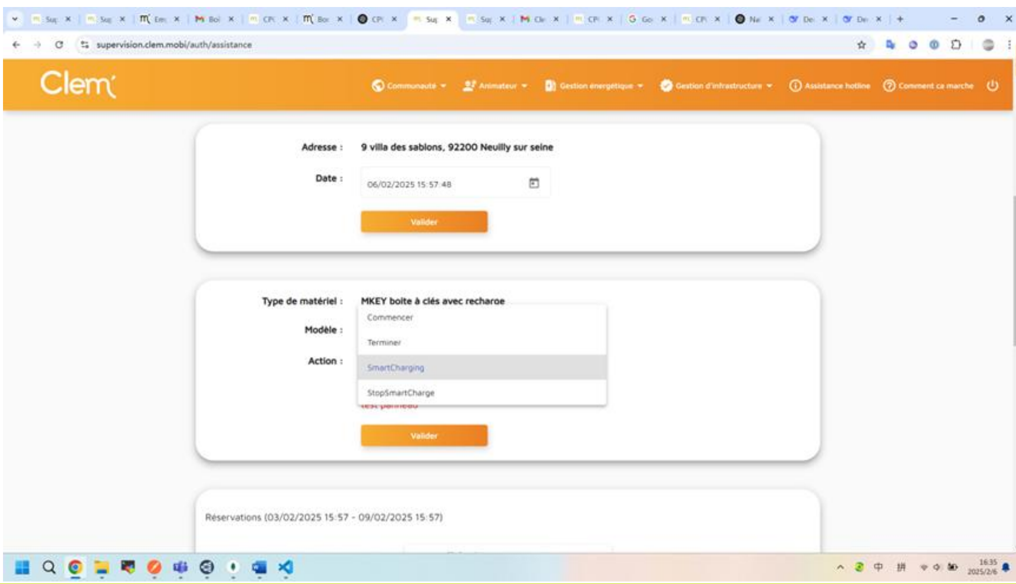


Test: A direct command from the **Linky meter** is used to restart the session.

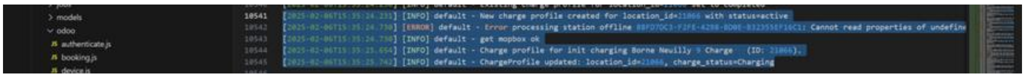
Smart charging pauses charging during Peak periods and resumes in Off-Peak. Forced Charging overrides Linky commands. Charging curves confirm correct suspension and restart behavior.

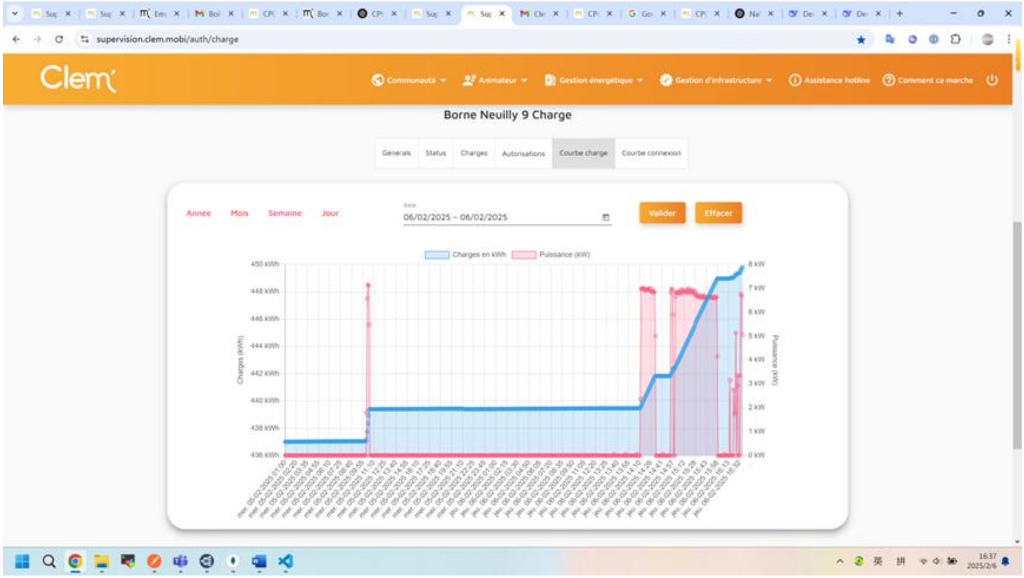
	
Objectives	FORCE MANUAL USE WHILE USING THE SMART METER (LINKY) FOR HP/HC CONFIGURATION
Evaluation	In this configuration, the platform overrides the HP/HC command from the Linky meter. The charging session starts and continues without interruption.  Smart charging pauses charging during Peak periods and resumes in Off-Peak. Forced Charging overrides Linky commands. Charging curves confirm correct suspension and restart behavior
Objective	USE THE HEMS/CPO PLATFORM (supervision. clem.mobi) FOR HP/HC CONFIGURATION

Evaluation	**Configuration:** Clem' platform integration V1G mode enabled  => communication between the HEMS/CPO platform and the charging station for V1G operations In this setup, there is **no limitation on total power** (set to a very high threshold). HEMS /CPO Platform configuration for HP/HC V1G  Automatic charging starts 5 minutes after the user arrives home (around 8:15 p.m.). Then, charging pauses until off-peak hours begin (here at 10:00 p.m.). Finally, the vehicle stops charging (in this case quite quickly, as it was already at 85% state of charge).

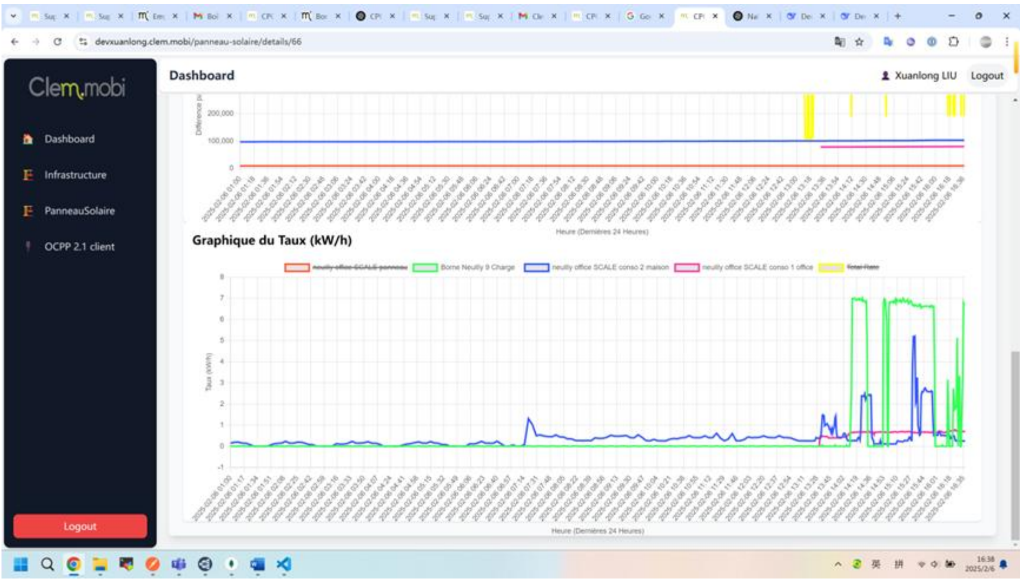
	Platform-based V1G logic starts charging automatically when the SP are producing, pauses during Peak periods, then resumes during Off-Peak. Charging events align with solar production and tariff schedule.
Objective	USE THE LINKY AND THE HEMS/CPO PLATFORM TO ERASE (or offset) THE VEHICLE CHARGING IN ORDER TO MANAGE THE TOTAL POWER SUBSCRIPTION OF THE HOUSE
Evaluation	HEMS/CPO platform configuration  If the house starts consuming more than 4 kW, the charging must stop in order to stay below a total of 12 kW. The user chooses smart charging 

Condition satisfied and enforced by the algorithm



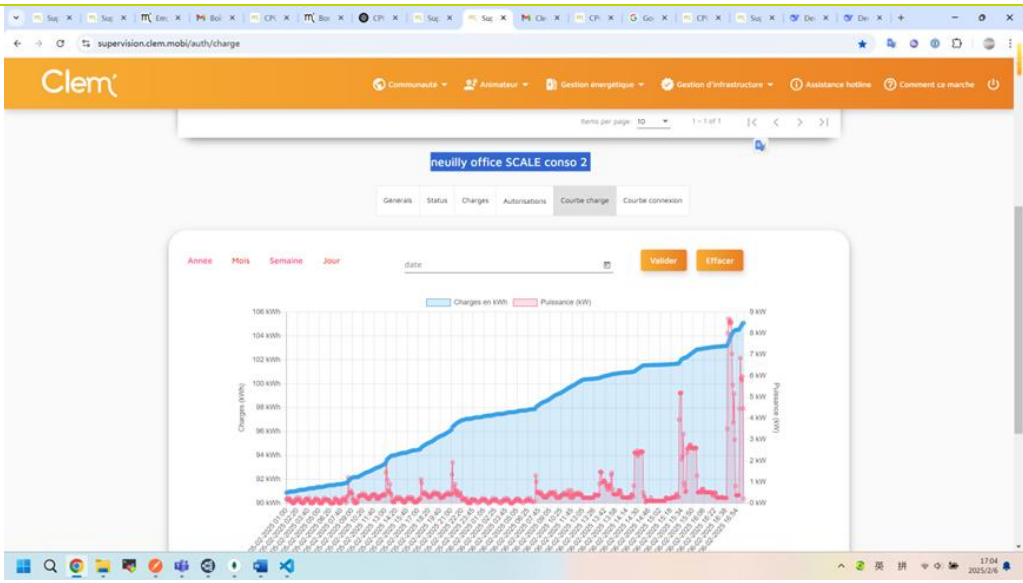


Loading curve of the charging station



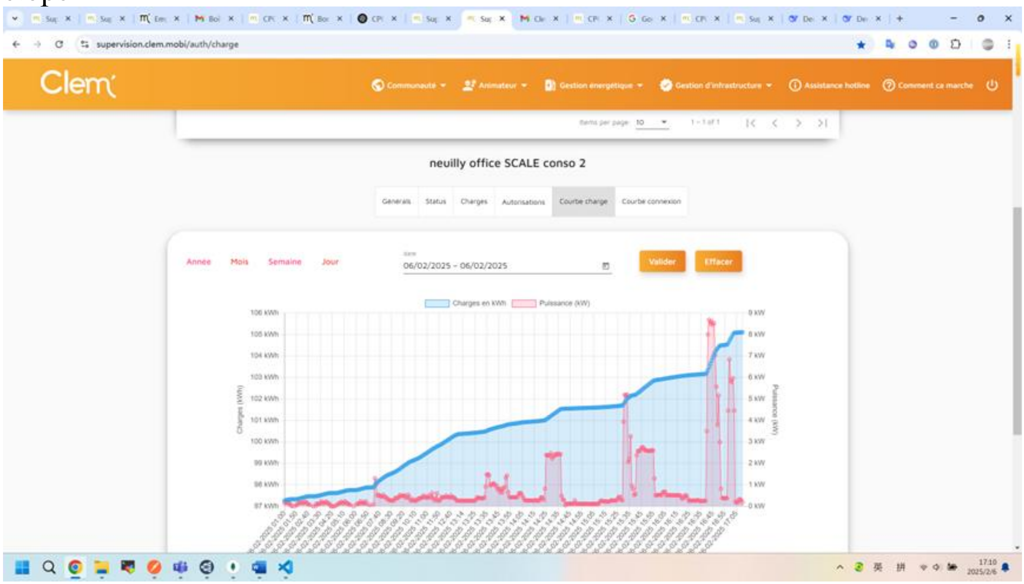
HEMS curves

Then the consumption of the house starts to increase significantly.

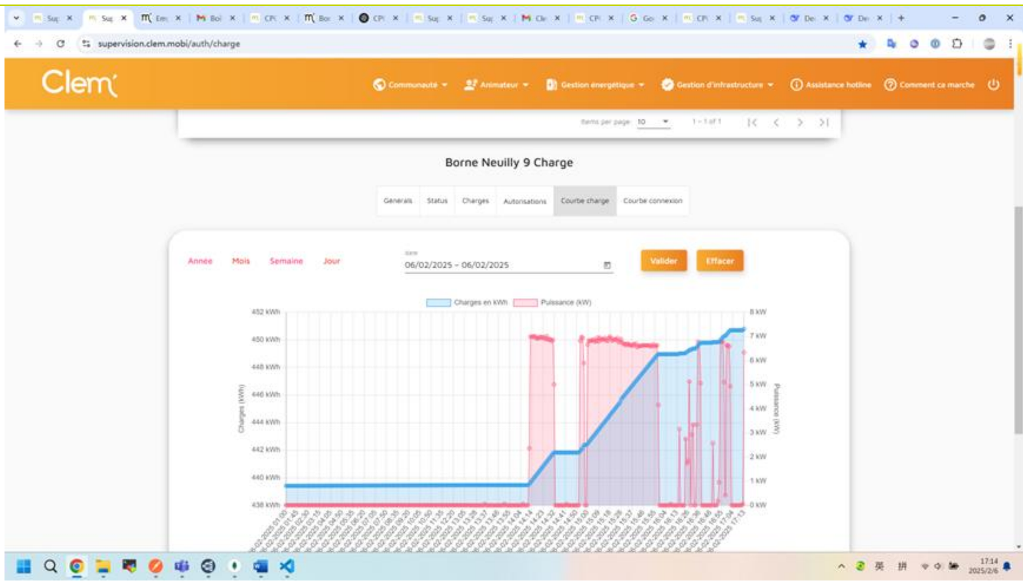


House consumption curve

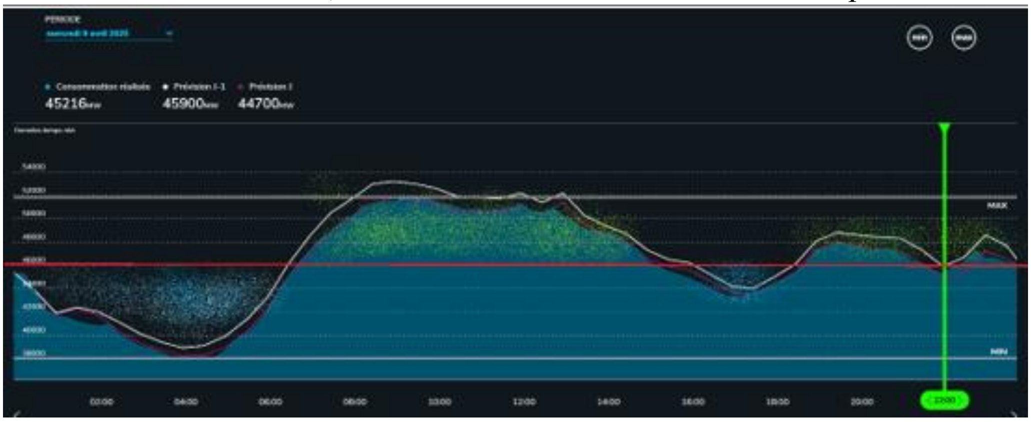
As the charging cession was at 6,68 kW, the charging cession automatically stops



The housekeeper stops cooking, the oven stops

<table>
<tr><td></td><td>

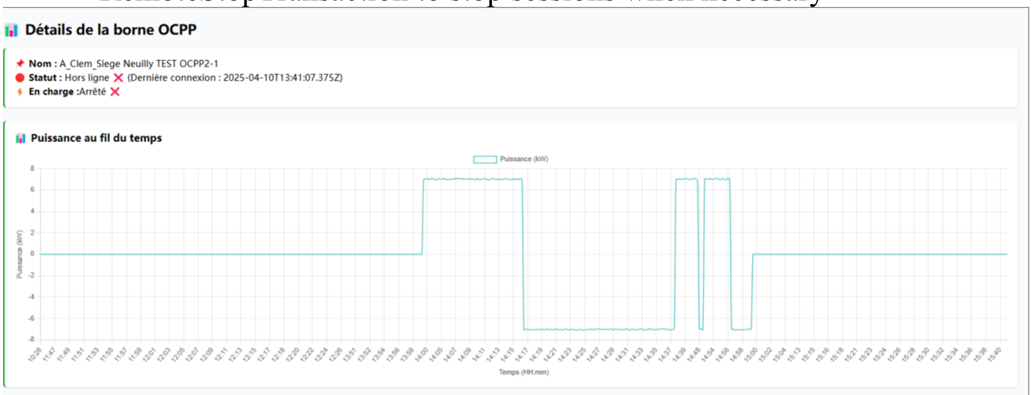
The charging cession re starts

Charging stops automatically when total house consumption approaches the subscription limit, and restarts once consumption decreases. Curves show correct enforcement of thresholds.</td></tr>
<tr><td>Objective</td><td>V1G/V2X FLEXIBILITY BASED ON NATIONAL RTE'S LOAD CURVE
&
SIMULATION OF STOP CHARGING IN CASE OF RTE' ALERT (ECO-WATT)</td></tr>
<tr><td>Evaluation</td><td>24 hour national load test, downloaded from RTE website 2025 April the 9th


Time segmentation of the simulation:

Real time | Simulated time | Consumption | OCPP action</td></tr>
</table>

<table>
<tr><td></td><td>
00:00 – 06:45 | 00:00 – 16:52 | < 46,000 MW | Charging
06:45 – 15:15 | 16:52 – 38:07 | ≥ 46,000 MW | Discharging
15:15 – 18:45 | 38:07 – 46:52 | < 46,000 MW | Charging
18:45 – 21:30 | 46:52 – 53:45 | ≥ 46,000 MW | Discharging
21:30 – 22:15 | 53:45 – 55:37 | < 46,000 MW | Charging

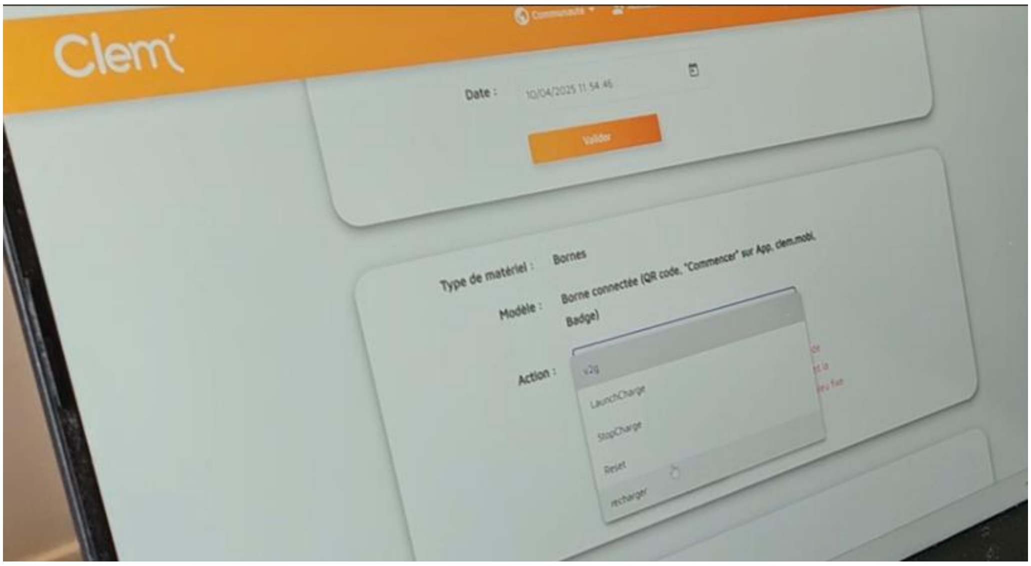
The OCPP system automatically applies charging or discharging commands according to the simulated schedule. These commands include:
• RemoteStartTransaction to start charging
• SetChargingProfile to adjust the power profile according to the selected mode (charge or discharge)
• RemoteStopTransaction to stop sessions when necessary


The system applies charge/discharge commands based on RTE consumption thresholds. OCPP commands control transitions. Charging/discharging aligns with simulated grid load periods.
</td></tr>
<tr><td>Scope</td><td>
V2H, V2X OPERATIONS BETWEEN INDEPENDANT STAKEOLDERS CPO/CHARGING STATION MAKERS/ EV OEM / DSO

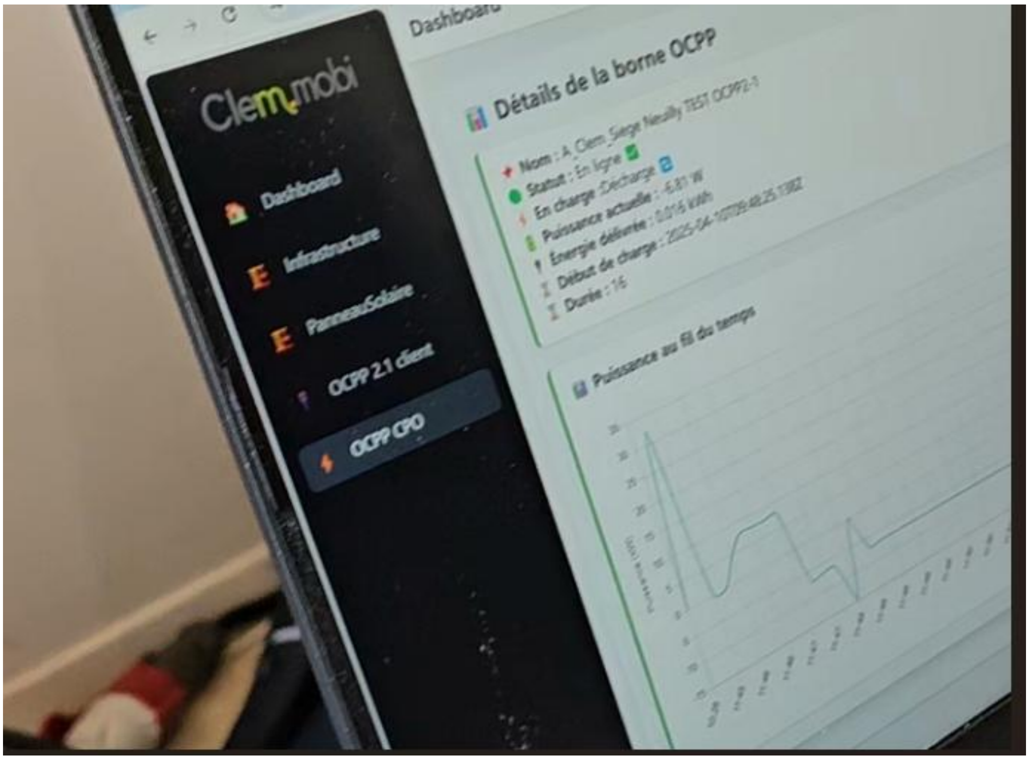
The demonstration was conducted collaboratively with teams from Enedis, EDF, Vedecom, Ampere, and Clem’, marking a significant milestone in Europe: the first successful interoperability test between a CPO platform provider, a V2G charger manufacturer, and a V2G-capable electric vehicle OEM—all from different entities.

🔋 A Renault R5 was used to perform V2G operations via the Vedecom charger, orchestrated by the Clem.mobi V2G platform
</td></tr>
<tr><td>Objective</td><td>
V2H (VEHICLE-TO-HOME): ENERGY WAS DISCHARGED FROM THE R5 TO POWER A BUILDING DURING A CONSUMPTION PEAK.
</td></tr>
</table>

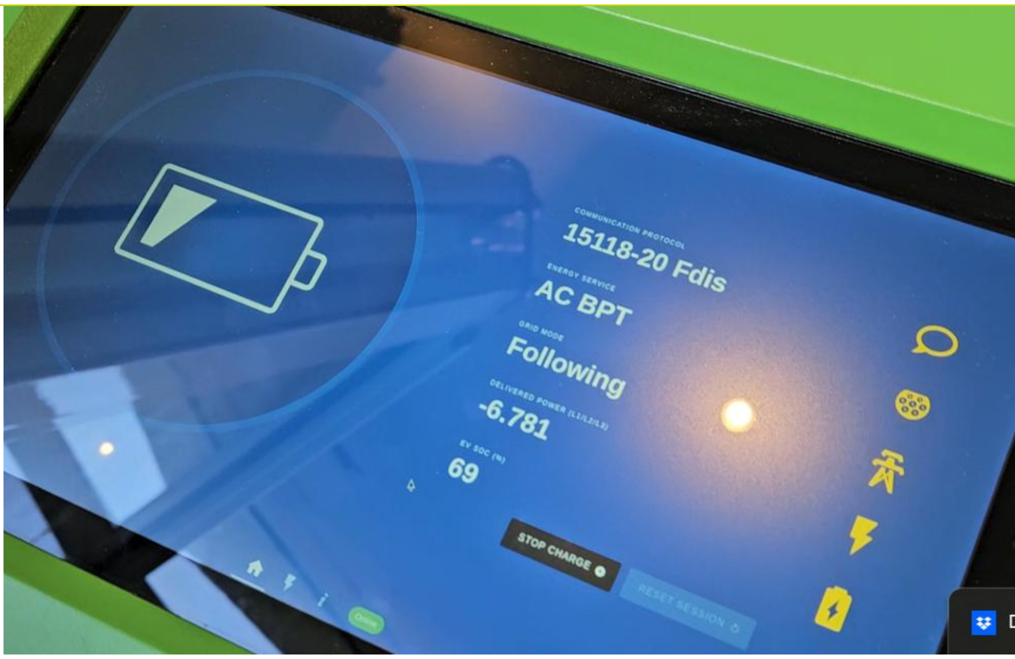
<table>
<tr>
<td>Evaluation</td>
<td>
V2H - The supervisor chooses V2G on the HEMS/CPO platform



The OCPP2.1 platform enables V2G operations



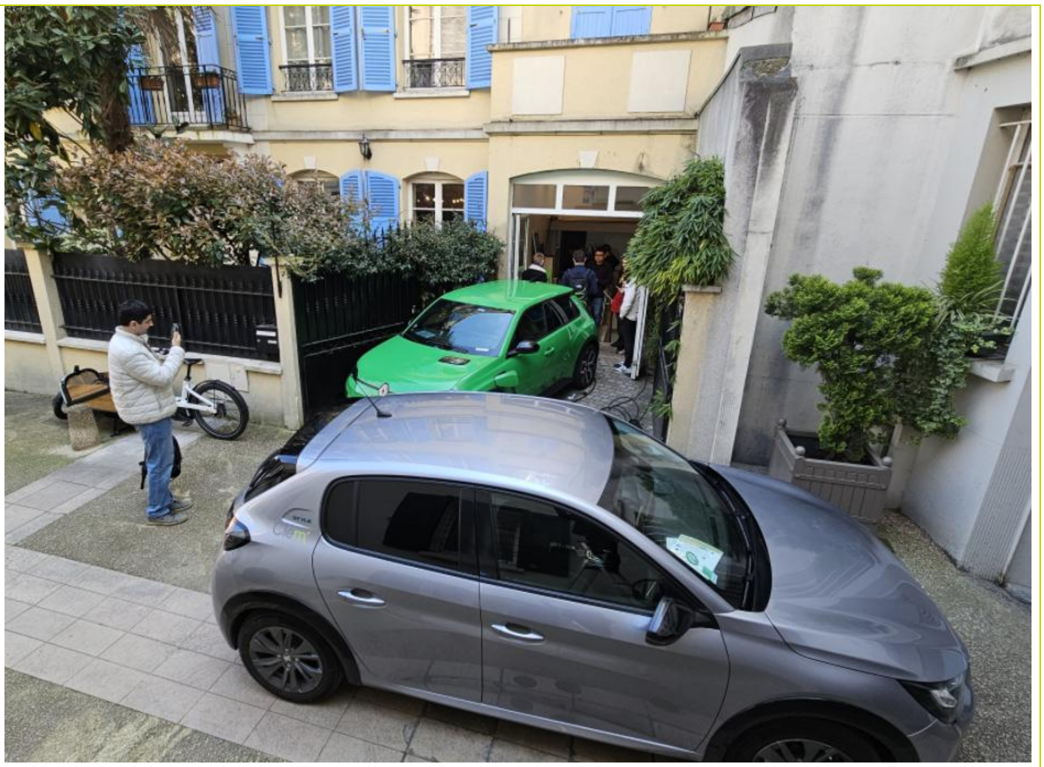
The charging station turns to discharge mode
</td>
</tr>
</table>



The car is in discharge mode

Automated action triggered from the CPO platform to turn back to charge mode

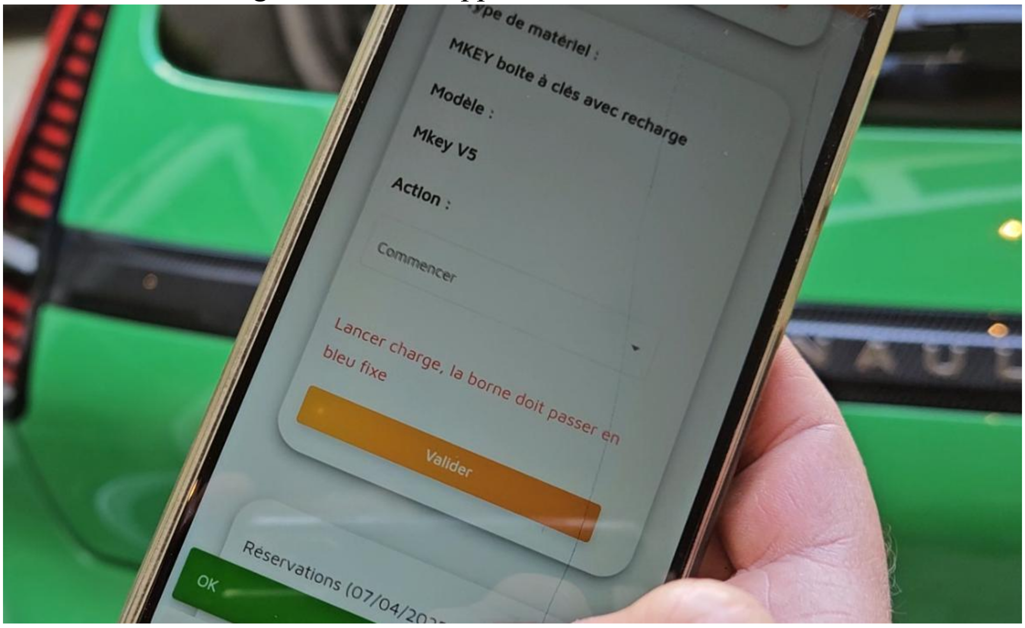
	 Measurements taken by EDF R&D showed no grid disturbances were occurred while V2G operations were running  The Interoperability fully worked and no grid disturbances was initiated by the tests
Objective	V2L (Vehicle-to-Load): THE R5 DISCHARGED IN MODE 3 TO CHARGE A PEUGEOT e208 IN MODE 2.
Evaluation	V2L: The V2G and the V1G charging stations are connected to the house and the HEMS/CPO platform



The charging station is in discharge mode (observed by VEDECOM charger)

The V2G car discharges (observed in the EV R5)

The user starts charge on his clem application for his e208



The Clem's V1G charging station turns ON (blue)

	 The e208 is charging  Dashboard of the e208 charging The interoperability behind the meter fully worked and power quality measurement were satisfied.
Objective	BIDIRECTIONAL BUILDING INTERACTIONS: CHARGING AND DISCHARGING EVENTS WERE SYNCHRONIZE WITH REAL-TIME SOLAR PRODUCTION FROM THE BUILDING'SPHOTOVOLTAIC SYSTEM
Evaluation	This demonstrator highlights the strategic value of smart charging (V1G and V2G) to maximize both individual and collective self-consumption, as opposed to injecting excess power back into the grid—a practice that has

	become economically unviable due to the significant drop in feed-in tariffs since March 2025.  With the protocol only recently validated by the Open Charge Alliance (OCA) on January 25, 2025, Clem' successfully demonstrated on April 10, 2025, that its V2G (Vehicle-to-Grid) platform is fully operational and compliant. The use case presented involves both charging and discharging operations, managed from Clem's end-user interface, relayed through the Clem OCPP 2.1 server, and connected to a 7kW AC V2G charger provided by Vedecom validated by the charging station and the vehicle and coordinates operations at the V2H level.

Evaluation KPIs/ upscaling potential	
Objective	REDUCE COST OF ELECTRICITY AT A HOUSE LEVEL THANKS TO V1G/V2G
Evaluation	The algorithm has been developed and used with a first V1G solution, with a one year data set.

Mode classique (Solaire + Bâtiment + Ct (PDC 1))

Heure	Solaire (P)	Bâtiment (C)	Ct (PDC 1)	Solaire Utilisé (AC)	Besoins Réseau
0:00	0.00	0.20	0.00	0.00	0.20
1:00	0.00	0.19	0.00	0.00	0.19
2:00	0.00	0.11	0.00	0.00	0.11
3:00	0.00	0.19	0.00	0.00	0.19
4:00	0.00	0.15	0.00	0.00	0.15
5:00	0.00	0.00	0.00	0.00	0.00
6:00	0.00	0.18	0.00	0.00	0.18
7:00	0.69	0.30	0.00	0.30	0.00
8:00	0.57	0.35	0.00	0.35	0.00
9:00	0.33	0.19	0.00	0.19	0.00
10:00	0.06	0.19	8.94	0.06	9.07
11:00	0.12	0.18	8.38	0.12	8.44
12:00	0.00	0.40	8.16	0.00	8.57
13:00	1.62	0.44	4.72	1.62	3.54
14:00	2.82	0.41	0.00	0.41	0.00
15:00	4.32	0.41	0.00	0.41	0.00
16:00	4.86	0.40	0.00	0.40	0.00
17:00	1.92	0.36	0.00	0.36	0.00
18:00	0.57	0.41	0.00	0.41	0.00
19:00	0.24	0.55	0.00	0.24	0.31
20:00	0.51	0.51	0.00	0.51	0.00
21:00	0.66	0.23	0.00	0.23	0.00
22:00	0.00	0.21	0.00	0.00	0.21
23:00	0.00	0.20	0.00	0.00	0.20
Total				**5.60**	**31.36**

Mode V1G (Solaire + Bâtiment + Cr v1g (PDC 1))

Heure	Solaire (P)	Bâtiment (C)	Cr V1g (PDC 1)	Solaire Utilisé (AC)	Besoins Réseau
0:00	0.00	0.20	0.00	0.00	0.20
1:00	0.00	0.19	0.00	0.00	0.19
2:00	0.00	0.11	0.00	0.00	0.11
3:00	0.00	0.19	0.00	0.00	0.19
4:00	0.00	0.15	0.00	0.00	0.15
5:00	0.00	0.00	0.00	0.00	0.00
6:00	0.00	0.18	0.00	0.00	0.18
7:00	0.69	0.30	0.00	0.30	0.00
8:00	0.57	0.35	0.00	0.35	0.00
9:00	0.33	0.19	0.00	0.19	0.00
10:00	0.06	0.19	0.00	0.06	0.13
11:00	0.12	0.18	0.00	0.12	0.06
12:00	0.00	0.40	0.00	0.00	0.40
13:00	1.62	0.44	0.00	0.44	0.00
14:00	2.82	0.41	1.96	2.38	0.00
15:00	4.32	0.41	8.54	4.32	4.63
16:00	4.86	0.40	8.32	4.86	3.86
17:00	1.92	0.36	1.48	1.84	0.00
18:00	0.57	0.41	0.00	0.41	0.00
19:00	0.24	0.55	0.00	0.24	0.31
20:00	0.51	0.51	0.00	0.51	0.00
21:00	0.66	0.23	0.00	0.23	0.00
22:00	0.00	0.21	4.42	0.00	4.63
23:00	0.00	0.20	5.48	0.00	5.68
Total				**16.24**	**20.71**

Comparaison des coûts :
Coût total mode classique : **7.69 €**
Coût total mode V1G : **4.83 €**
Économie avec V1G : **37.2%**

The result of our study based on Clem's data shows that

If the average total cost of a charge in classic mode for the user is 7,69€,
The average of a total cost of a charge in a V1G mode for the user is 4,83 €
The savings achieved through V1G amount to 37,2%

Objective	OFFER AN AFFORDABLE SOLUTION FOR THE HOUSING SECTOR
Evaluation	The demonstrator has proven the feasibility of an affordable solution for the housing sector, integrating in one hand CPO and HEMS The certification process between third party is the challenge of AC V2G interoperability The CPO labeled by both the DSO and the OEM could probably manage the certification process

Evaluation Charging services	
AC	The platform OCPP2.1 Clem performed managing the V2G AC R5 from Renault and no disturbances occurred on the micro grid and the grid

Evaluation Energy Management Services

Evaluation	The fully integrated platform connecting in one hand a OCPP2.1 CPO platform and a HEMS MQTT platform enabled to perfectly manage the charging and discharging of the R5 in full interoperability with three independent stakeholders

Evaluation System architecture	
Control topology	*DSO Commands* *HEMS logic* *CPO backend decisions* *Charger internal logic* *EV Response*
Evaluation	The control topology was validated successfully during the pilot. The system demonstrated stable coordination between all control layers: Linky (DSO), HEMS, the CPO backend, the AC V1G/V2G charger and the V2G-capable EV. Priority rules were correctly enforced: Linky commands overrode platform decisions, followed by the HEMS optimisation logic, and finally user preferences.
Communication protocols	*OCPP1.6/2.1+MQTT, Modbus, dry contact*
Evaluation	The communication protocols used in the pilot were validated successfully. MQTT communication between smart meters and the HEMS operated continuously without data loss, enabling real-time retrieval of household consumption, PV production and charging power. OCPP (1.6 and 2.1-ready) communication between the CPO backend and the charging station remained stable during all V1G and V2G operations, including rapid transitions between charge, pause and discharge modes.

Evaluation of overall pilot results
Based on the results of the A1.1 “Smart and Bidirectional Home Charging” pilot, Clem identified several important technical, operational, and strategic insights: 1. Successful validation of an open, interoperable V2G ecosystem The pilot demonstrated that an AC V2G system can operate reliably across independent stakeholders—CPO platform (Clem), V2G charger manufacturer (Vedecom), EV OEM (Renault), and DSO (Enedis). The system successfully handled charging and discharging commands through OCPP 2.1, proving interoperability between fully independent actors and confirming compliance with the newly validated OCA specifications. 2. V1G smart charging delivers substantial cost savings for end users Using one year of real household load data, the pilot showed that V1G smart charging reduces average charging costs by 37.2% compared to uncontrolled charging. This demonstrates the strong potential of demand-side flexibility to reduce household electricity bills through load shifting to off-peak periods.

3. AC bidirectional charging is technically viable and cost-effective
The pilot confirmed that AC V2H/V2X can be a more affordable and scalable alternative to the currently more expensive DC systems.
This makes V2H accessible to a larger segment of households, especially in existing residential environments.

4. Real-time control based on grid conditions is effective and reliable
The system responded correctly to simulated RTE grid-stress periods by switching between charge and discharge modes.
This validates the ability of OCPP-based V2G to follow real-time grid constraints and contribute to balancing services such as peak shaving and consumption shifting.

5. Smart home integration works seamlessly through the HEMS/CPO platform
The combination of sub-metering, MQTT communication, and the unified CPO+HEMS platform allowed the system to:

- optimise self-consumption,
- prevent exceeding the household's grid subscription limit,
- react quickly to Linky signals (HP/HC and power system stress signal),
- give users real-time visibility and control of their charging preferences.

6. The pilot demonstrates tangible potential for grid services
Through coordinated charge/discharge cycles, the system showed its ability to support:

- peak load reduction,
- improved local self-consumption of solar production,
- reduced reinjection of surplus PV into the grid at low tariffs,
- support during power system stress scenarios.

This confirms the potential of V1G/V2G residential flexibility as a cost-effective solution to help DSOs manage peak loads in a future with high EV penetration.

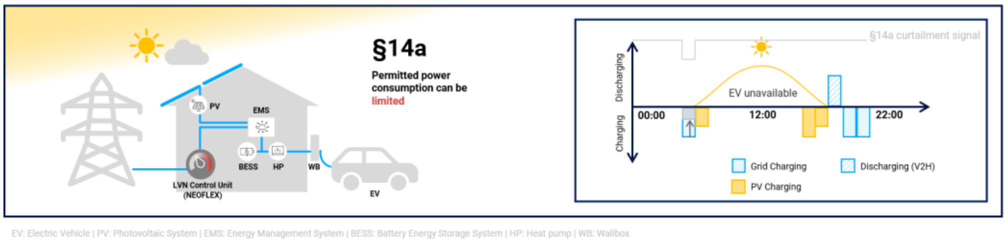
7. User-side control and supervisory tools are intuitive and effective
The test validated that both the end-user interface and the supervisory control interface allow:

- easy activation of smart charging modes,
- override functions (Forced Charging),
- confirmation of Ecowatt-based flexibility events,
- real-time monitoring of charging curves and household consumption.

This demonstrates that the system is ready for operational deployment with real users.

2.1.2 A1.2: Greater Munich with LEW. Extension to V2G services enabling participation in energy market

<table>
<tr><td>Use case lead</td><td>LEW</td></tr>
<tr><td>Use case context</td><td>The use case explores V2H-self-consumption-optimization operation in residential environments under real-world German grid and regulatory conditions (Power curtailment). It aims to test §14a EnWG-compliant control schemes that enable temporary power limitation by the distribution system operator (DSO) in case of local grid congestion.</td></tr>
<tr><td>Use case description</td><td>The use case aims to demonstrate how smart charging and V2H functionalities can be integrated into residential environments to enable both user-centric energy optimization and grid-oriented flexibility.



As shown in the figure above, the overall control logic is designed to follow the principles of §14a EnWG, enabling temporary DSO intervention in charging processes during periods of local grid congestion. In such cases, the charging power at the wallbox is expected to be reduced via the LEW Neoflex control unit to ensure compliance with grid-stability requirements. Beyond the grid-side control, the EMS is intended to monitor PV generation and vehicle state of charge to support self-consumption optimization without compromising mobility needs.

To implement the use case, the pilot will be carried out with three participating residential customers, each expected to be equipped with an ISO 15118-2 VAS-enabled EV, a bidirectional DC wallbox with integrated HEMS functionality supplied by Ambibox, and a photovoltaic system.</td></tr>
<tr><td>Use case goal</td><td>The use case aims to provide practical insights into the feasibility of implementing §14a EnWG-compliant power limitation schemes coordinated through standardized communication interfaces while maintaining user convenience and optimizing self-consumption of photovoltaic energy.</td></tr>
</table>

Use case scope The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Cluster				**A: Smart home charging**
Use case number				**A1**
Use case leader				**LEW**
Mobility services			Type of service	Private cars
Charging services		AC	Unidirectional	
			Bidirectional	
		DC	Unidirectional	✓
			Bidirectional	✓
			Fast charging	
Energy services	**Local behind-the-meter optimization**	Increase self consumption of on-site renewables	V1G	✓
			V2X	✓
		Reduce demand charges	V1G	
			V2X	
		Time-of-Use shifting	V1G	
			V2X	
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management (D1)	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	✓
			V2X	
		Power Quality control	V1G	
			V2X	
System architecture		**Control topology**	OEM	
			CPO	
			EM	✓
		Communication protocols	EV - Charger	ISO 15118-2 VAS
			Charger-EMS	OCPP 1.6-2.1
			Charger-CPO	n.a.
			CPO - SCSP	n.a.
			CPO - eMSP	n.a.

Evaluation pilot objectives	
Objective	Find the optimal concept for integrating an EV in a residential energy system using existing open standards.

Evaluation	The optimal concept for integrating an EV into a residential energy system using existing open standards has been defined through the system architecture developed for the LVN pilot. The design combines ISO 15118-2 VAS for EV<> Wallbox communication, OCPP 2.0.1/2.1 for Wallbox<>EMS/backend interaction, and §14a-capable control via the Smart Meter Gateway and Neoflex. This architecture meets the objective at conceptual level, with functional validation expected during the upcoming pilot phase. 
Objective	Determine the value of the optimized self-consumption (in combination with a residential PV system) of smart (unidirectional) charging and bidirectional charging in addition.
Evaluation	Preliminary simulations indicate that coordinated charging strategies have the potential to significantly increase PV self-consumption compared to uncontrolled charging. The introduction of bidirectional operation is expected to provide additional flexibility for local energy use and further reduce dependency on grid-supplied electricity. The actual quantitative impact will be assessed during the pilot phase once real operational data become available.
Objective	Determine and optimize the costs and benefits for the end user (e.g., hardware, installation & operational cost and savings on energy costs)
Evaluation	Cost structures for hardware and installation have been documented in cooperation with Ambibox as part of the pilot preparation. Operational cost savings are expected to be evaluated during the pilot phase. The resulting insights will support the development of a comprehensive cost-benefit benchmark for future §14a EnWG-compliant residential charging solutions.
Objective	Determine emotional aspects of customers from the pilot operation and a meta study over corresponding projects.
Evaluation	User acceptance and emotional factors are expected to be assessed during the pilot phase, with a focus on customer perceptions of temporary power limitations and the usability of the system. The evaluation will consider aspects such as perceived comfort, transparency of control actions, and overall satisfaction with the charging experience.
Objective	Reduce peak loads and optimize the overall interaction with the grid, based on the German latest legal framework (§14a EnWG and Smart Metering system with Smart Meter Gateway) in emergency cases (grid overload).

Evaluation	The pilot is expected to evaluate the ability of §14a EnWG-compliant control schemes to reduce peak loads by temporarily limiting charging power to the regulatory threshold. The interaction between the EMS, Smart Meter Gateway, and Neoflex is anticipated to demonstrate stable execution of curtailment commands during grid-relevant events. Overall, the pilot aims to assess how such control measures can mitigate local grid peaks while maintaining an acceptable level of user mobility.

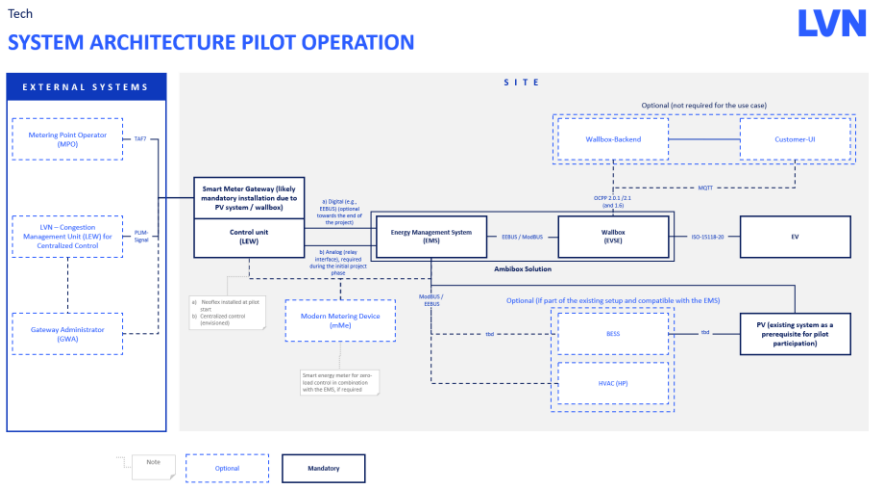
Evaluation KPIs/ upscaling potential	
Objective	Reduce energy exchange with the grid by >50 %.
Evaluation	Preliminary simulations indicate that reductions towards the 50 % target may be achievable under favorable PV and usage conditions. Actual performance will be evaluated during the pilot phase using real household energy data.
Objective	Increase PV self-consumption up to 70 % or higher.
Evaluation	The developed charging strategy is designed to increase PV self-consumption by aligning charging periods with daytime PV production and enabling V2H discharge cycles. Preliminary simulations suggest that self-consumption levels approaching the 70 % target may be achievable, depending on PV generation patterns and vehicle availability. The actual performance will be assessed during the pilot phase and monitored across different seasons.
Objective	Achieve an annual reduction of approx. 500 kWh of grid-supplied energy per household.
Evaluation	Preliminary simulations of bidirectional operation indicate that annual reductions in grid-supplied energy on the order of 400-550 kWh per household may be achievable. These estimates highlight the potential of household-integrated flexibility to reduce dependency on grid imports. The actual reduction will be quantified during the pilot phase based on measured energy flows.
Objective	Implement power curtailment signals (according to §14a EnWG) issued by the DSO and verify successful execution (> 90 % compliance rate).
Evaluation	The pilot setup is designed to enable §14a EnWG-compliant power curtailment via the Neoflex control unit and Smart Meter Gateway. The communication chain and control logic are expected to support reliable execution of curtailment commands, with compliance rates above 90 % anticipated under typical operating conditions. Actual performance, including response times and communication robustness, will be evaluated during the pilot phase.
Objective	Demonstrate replicability and scalability of §14a EnWG-compliant smart charging concepts across DSOs and technology providers.
Evaluation	The system architecture is designed to be replicable across DSOs and technology providers by relying on commercially available components and open communication standards. The coordination mechanisms between the DSO infrastructure and the EMS are expected to require only minimal adaptation for deployment in comparable environments.

Evaluation Charging services	
DC	

	For the purposes of the pilot, a DC/CCS setup was chosen to explore bidirectional operation, as it currently represents a feasible configuration for investigating V2H functionalities under real-life conditions. Since ISO 15118-20 is not yet available for deployment, V2H capability is enabled through ISO 15118-2 VAS extensions supported by the participating vehicles. This setup provides an appropriate technical basis for analysing coordinated V2H behaviour and §14a-compliant control within the project scope.

Evaluation Energy Management Services	
Evaluation	The bidirectional DC wallbox is designed to operate with an integrated EMS that manages local control and scheduling via OCPP communication. The wallbox is capable of measuring local power flows and report them to the backend, where the EMS is hosted. The EMS is intended to receive §14a EnWG curtailment signals via the Neoflex unit and Smart Meter Gateway and to implement these commands by adjusting the charging power at the wallbox during the pilot phase.
Primary objective Validate a system design capable of executing §14a EnWG-compliant charging limitation while maintaining user convenience.	
Evaluation	The EMS is expected to receive and interpret grid-side curtailment signals transmitted via the Neoflex control unit. During the pilot phase, the system is anticipated to execute these control actions reliably while restoring normal charging once the limitation is lifted. The evaluation will assess communication stability and the EMS's ability to balance user-defined charging targets with §14a EnWG requirements.
Secondary objective To increase PV self-consumption through coordinated charging and bidirectional Vehicle-to-Home operation within residential households.	
Evaluation	V2H operation are expected to increase PV self-consumption by aligning charging cycles with periods of on-site generation and enabling targeted discharge to household loads. Simulation-based assessments suggest that noticeable improvements may be achievable depending on PV availability and vehicle connection patterns. The actual impact on self-consumption levels will be evaluated during the pilot phase using measured operational data.

Evaluation System architecture	
Control topology	The system architecture is designed to manage charging and discharging processes according to §14a EnWG control requirements. It is expected to calculate setpoints based on PV generation data and curtailment signals received through the Neoflex control unit. The pilot phase will evaluate how effectively the developed system implements these setpoints and maintains coordination between user preferences and grid-related constraints.

Evaluation	The system is expected to execute both user-driven and DSO-triggered control commands in real time. The control logic is designed to maintain stable operation during grid-relevant limitation events and to automatically restore normal charging once the curtailment signal is released. Actual performance will be assessed during the pilot phase.
Communication protocols	EV <> DC Charger: ISO 15118-2 VAS protocol DC Charger <> WB Backend: OCPP 2.0.1/2.1 (and 1.6) DC Charger <> EMS: EEBus/ModBUS EMS <> PV: EEBus Neoflex <> EMS: Analog relay-based interface An overview of the communication protocols intended to be used in the pilot setup is provided in the figure below. An overview of the communication protocols intended to be used in the pilot setup is provided in the figure below.
Evaluation	Communication between the EV and the charger is expected to remain stable across all operating conditions. The ISO 15118-2 VAS protocol is designed to enable seamless transitions between charging and discharging modes, which will be validated during the pilot phase.
	 The system architecture is designed to establish a fully functional end-to-end communication chain between the distribution system operator (DSO), the energy management system (EMS), and the EV. The figure above provides an overview of the communication protocols implemented for the setup. At the household level, the EV is expected to communicate with the bidirectional DC charger via ISO 15118-2 VAS, enabling secure exchange of charging parameters, authentication, and bidirectional control information. The charger is designed to interact with the integrated EMS via OCPP 2.0.1/2.1 (and 1.6). The Ambibox app will provide the user interface for setting charging preferences and monitoring the charging process in real time. For energy coordination,

	the PV inverter is expected to communicate its generation data directly to the EMS, and the setup is designed to allow integration of additional assets such as a stationary battery energy storage system (BESS) or other controllable devices. On the grid side, the EMS is intended to interface with the Smart Meter Gateway (SMGW) and Neoflex, which provide the communication channel for §14a EnWG curtailment signals and measurement data from the modern metering equipment (mMe).

Evaluation of overall pilot results
The key takeaways expected from the pilot are: 1. Validated system architecture (conceptual level): The pilot establishes a §14a EnWG-compliant bidirectional system architecture based on open standards (ISO 15118-2 VAS, OCPP, SMGW/CLS), demonstrating conceptual feasibility for coordinated residential smart charging. 2. Expected stable DSO control: The control chain via Smart Meter Gateway and Neoflex is designed to support reliable execution of curtailment signals, with high compliance rates anticipated under typical operating conditions. 3. Expected improvement in PV self-consumption: Coordinated EMS control, including V2H operation, is expected to increase PV self-consumption and reduce household grid imports, as indicated by preliminary simulations. 4. Expected user acceptance: User feedback during the pilot phase will assess acceptance of temporary power limitations, with transparency and ease of use anticipated to support positive perception. 5. Scalable and replicable design: The planned setup is designed to be scalable across DSOs and technology providers through the use of commercially available components and standardized communication protocols.

2.2 Innovation cluster B: Smart charging at businesses & offices

This innovation cluster focusses on smart charging and V2X in the context of business and offices. For employees parked at their office, the charging time is typically not of key importance. What is important is that there is sufficient range for commuting or business travel. This scenario represents potential for smart charging and V2X services because of the central control of charging, long stationary times and an already high uptake of EVs in company fleets. The potential identified also includes reducing costs through self-generation and self-consumption as well as demand charge reduction. As a result, increasing the use of locally generated renewable energy and lowers the peak loads on the grid.

2.2.1 B1 Grid-friendly, Vehicle 2 Building station-based car sharing service for commercial real estate tenant companies

Use case lead	**Serviced Office Belbuda, DBH Group - Zsolt Puja**
Use case context	The use case takes place in Hungary, in Debrecen on a DBH owned office building. The purpose of this use case is to test a unique energy ecosystem specifically designed for office buildings, which has not yet been implemented in such environments. This interconnected setup aims to evaluate the feasibility and performance of an innovative energy management solution in office buildings in order to support the energy usage of the building and its tenants, such as an EV car-sharing service as required. To stimulate access to EVs, the service is planned to be provided to tenants as part of the serviced office service package.

Use case description	The system includes an installation of a 19,14 kWp DC solar power installation and a battery energy storage unit (Huawei LUNA 2000 5 kW, modular in 5 kW increments for expansion), integrated with an electric vehicle charging station. One DBH office location will be supplied with office-carsharing cars. The first objective of the pilot is to determine the optimal business model for the proposed new commercial office car-sharing service in Europe, including clearly identify customer segments on the market, and therefore we could adjust the business model for their needs. The second objective of the study is to identify a scalable, yet efficient solution, how the GoodMoovs platform can be integrated with DBH SO's customer management software and business processes. The third objective is to set up and experiment with the demand side load management smart charging feature, covering the integration between the vehicle, the recharging point, the building energy management system, and the grid operator, and prepare the blueprints for a suitable technical solution, which enables the use of the new service in a commercial office building environment and beyond. The development and testing of the unique energy management system is carried out in partnership with E Mobility Solutions and Enervalis.  We estimate that for a rental company, compared to alternative solutions, the solution offered could save up to 40% in costs and significantly reduce CO_2 emissions, and could be offered as a benefit in kind to employees, increasing employee satisfaction. The use case aims to set up and experiment with the demand side load management smart charging feature, covering the integration between the vehicle, the recharging point, the building energy management system, and the grid operator.
Use case goal	The use case focuses on two primary objectives. The first is the implementation of a fully integrated energy management solution in our office building, enabling unique, overlapping measurement and testing of

	energy consumption and production. This innovative system is specifically designed for office buildings and supports efficient energy use, including integration with electric vehicle (EV) charging infrastructure. The second objective is to launch and provide a related car-sharing service for our clients. This service will offer a fully electric, station-based car-sharing model, tailored to the serviced office market. It will be made available as part of the office service package, allowing tenants to use the service for business purposes or offer it as an employee benefit. This solution aims to enhance employee satisfaction and support sustainable transportation.

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Cluster				**B: Smart charging at businesses/ offices**
Use case number				**B1**
Use case leader				**DBH**
Mobility services			Type of service	Car-sharing
Charging services		AC	Unidirectional	✓
			Bidirectional	
		DC	Unidirectional	
			Bidirectional	
			Fast charging	
Energy services	**Local behind-the-meter optimization**	Increase self consumption of on-site renewables	V1G	✓
			V2X	
		Reduce demand charges	V1G	✓
			V2X	
		Time-of-Use shifting	V1G	✓
			V2X	
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management (D1)	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	
			V2X	
		Power Quality control	V1G	
			V2X	
System architecture		**Control topology**	OEM	
			CPO	
			EM	✓
		Communication protocols	EV - Charger	ISO 15118-20
			Charger -EMS	OCPP 1.6
			Charger -CPO	OCPP 1.6
			CPO - SCSP	n.a.
			CPO - eMSP	n.a.

Evaluation pilot objectives	
Objective	Create a positive business case of the EV car sharing program for the supply and demand side.

Evaluation	Our initial attempts were unfortunately delayed, as the owners of DBH rented office properties were not receptive to the implementation of the solution and building work needed to achieve it. As a result, the entire service had to be relocated to properties under DBH ownership. The service will be tested on the new, fully owned and operated sites.
Objective	Cost reduction through smart charging integrated with the building EMS and local renewable energy generation.
Evaluation	A solar energy system with battery storage was installed, integrating 42 solar panels with a Huawei LUNA 2000 5 kW (BESS) energy storage unit for local renewable energy generation. The chargepoint, an AC Etrel INCH PRO 22 kW EV charger, was integrated into the building's energy management system to complete the installation. This setup allows us to both test a unique integrated internal energy management ecosystem in office buildings whilst also saving on energy costs.
Objective	Cost reduction by V2X service (self-consumption).
Evaluation	Deployment of V2X capable equipment is still in progress and not yet included the current results. In Q1 & Q2 2025 it is expected that all the equipment will be in place and the integrated system will be able to leverage V2X services in order to achieve cost reduction.
Objective	Increase use of the car sharing program by determining what influences mobility mode choice.
Evaluation	Testing is ongoing, more precise data will be available once there will be significant amount of trips to analyse.

Evaluation KPIs/ upscaling potential	
Objective	Expand the E-car sharing program from 4 to 256 cars during SCALE.
Evaluation	The deployment of the purchased BYD vehicles was delayed and the objectives was not attained by publication date but results are expected before Q2 2025.
Objective	Increased end user satisfaction with 50%.
Evaluation	Since car sharing is not operational, yet we have no live data supporting this
Objective	Increase utilization rate of chargers by 50%.
Evaluation	Due to the change of site, the baseline measurement is zero as the new site was not previously equipped with a charger, therefore with the new installation the usage has already increased, charging took place 3-4 times a week since.
Objective	Policy development in Debrecen and Budapest.
Evaluation	Significant improvements have been done to the energy infrastructure of the Debrecen office.
Objective	Minimize trip failure by 10%.
Evaluation	Testing is ongoing, more precise data will be available once there will be a significant amount of trips to analyse.
Objective	Increase share of RE used for charging by 20%.

Evaluation	Due to the change of site, the baseline measurement is zero. That said, with the integrated 42 solar panels and BESS system, and with the size of the EV fleet, this objective is comfortably expected to be achieved when calculated over a 12 month period.

Evaluation Charging services	
AC	AC Etrel INCH PRO 22 kW EV charger was installed and connected to the building's energy management system.

Evaluation Energy Management Services	
1. Primary objective Optimization of smart charging features in connection with car sharing operation	
Evaluation	A solar energy system with battery storage and an integrated EV charger has been implemented within the building's energy management system. This setup optimizes smart charging and energy efficiency by integrating renewable energy with the building's charging infrastructure.
2. Secondary objective Reducing building's electrical power capacity and saving operational costs this way	
Evaluation	The demonstrations are ongoing and the results will be evaluated in terms of cost reduction for the different scenarios.

Evaluation System architecture	
Control topology	*CPO*
Evaluation	
Communication protocols	*OCPP*
Evaluation	

Evaluation of overall pilot results
Any use-case development, or the launch of a new service is proposed only on private property. Installing equipment in a rented building is very challenging as landlords are systematically not aware or supportive. As such, policy developments mandating their support would be recommended. Electric vehicles are difficult to purchase as they have long delivery times and prices are rising rapidly which makes it hard to create a business case around multiple moving targets. Equipment needs to have service contracts to ensure operation throughout project/lifetime and vehicle systems need to be included for an effective energy system.

2.2.2 B2 Future proof energy management and V2G pilot at Duna Auto, a multi brand car dealership in Budapest

Use case lead	**EMS : Janos Ungar, Zoltan Meszaros**
Use case context	The use case is situated at Duna Auto, one of the largest multi brand car dealerships in Budapest, Hungary. With the help of a newly designed internal electricity and communication network at the dealership and repair centre we will demonstrate how such a system including a complex PV system, a cluster of smart charging stations and an industrial scale storage system enables to maximize the level of renewable energy usage and decreases dependence from public electricity network while also making use of the battery capacities of the vehicles parked at the site as buffer and as balancing capacity as well.  The V1G charge points (installed by EMS prior to the SCALE project) can be used by customers or staff with any EV. The 2 units of ABB 11 kW DC V2G will be used within SCALE project with V2G compliant cars for selected users for testing purposes.
Use case description	At the Emobility Solutions use case, there are several buildings at the site, also positioned as one of Hungary's smart energy and electromobility demonstrational and living labs, where a bidirectional charger will be installed to demonstrate V2G functionality. The buildings are equipped with a 400kWp rooftop solar PV.  There are already over 30 charging points in operation (including AC and DC technologies) and 2 have been replaced with ABB bidirectional chargers as part of SCALE project. A V2G compliant EV would be used in the demonstrations in 2025.

Use case goal	The main goals with this use case are: • One of the main goals is to increase the self-consumption of the onsite solar PV through V1G and V2G technology. Through V1G CP, this is achieved by charging the EV when there is excessive PV production. Using the V2G CP, this is achieved by saving the extra power of solar PV at sunny time by charging the EV and realising the energy (discharging the EV) when required in the building at peak time. • Reduction of the electricity bills for the building is another important goal to be achieved in this use case. In this scenario, the EV will be charged at off-peak time when the electricity price is low and will be discharged at peak times when the demand for electricity is high. • Due to high power tariffs, reducing the peak load is another goal to be achieved by this use case. In this scenario, the EV scheduling will be done to not charge the EV at peak time, and if possible to discharge it during that period. As a conclusion this use case will demonstrate the following scenarios: • Solar charging • Load management • V2G peak shaving 

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				**B: Smart charging at businesses/ offices**
Use case number				**B2**
Use case				**Emobility Solutions**
Mobility services			Type of service	Private & company cars
Charging services		AC	Unidirectional	✓
			Bidirectional	
		DC	Unidirectional	✓
			Bidirectional	✓
			Fast charging	
Energy services	**Local behind-the-meter optimization**	Increase self consumption of on-site renewables	V1G	✓
			V2X	✓
		Reduce demand charges	V1G	✓
			V2X	✓
		Time-of-Use shifting	V1G	✓
			V2X	
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	
			V2X	
		Power Quality control	V1G	
			V2X	
System architecture		**Control topology**	OEM	
			CPO	✓
			EM	✓
		Communication protocols	EV - Charger	ISO 15118-2 / ISO 15118-20
			Charger -EMS	OCPP 1.6, OCPP 2.0.1
			Charger -CPO	OCPP 1.6, OCPP 2.0.1
			CPO - SCSP	***t.b d.***
			CPO - eMSP	n.a.

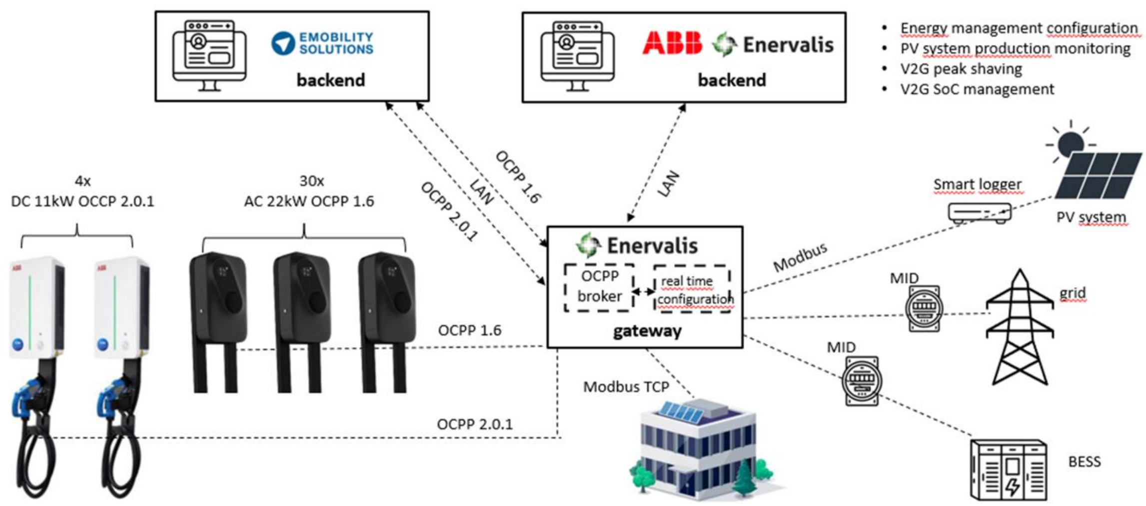
Evaluation pilot objectives	
Objective	Increase utilization of generated renewable energy through self consumption, demand charge reduction, and energy storage.
Evaluation	Through our backend we can monitor the locally generated electric power and setup scenarios of the optimal utilization favouring self consumption, demand charge reduction, and energy storage.
Objective	Cost reduction through an increase utilization of renewable energy and reduced peak loads.
Evaluation	With the installed PV system, and the smart charging capabilities of our backend system we can setup scenarios for cost reduction for the use case site owners; prioritising locally generated, cheaper energy and smoothening out the loading curve based on the required target SOC in combination with target departure time.
Objective	Improve power system quality through increased flexibility from the V2G service.
Evaluation	As of 2024, the use case is operational with V1G smart charging with an expectation that V2G services will be available for Q2 2025.

Evaluation KPIs/ upscaling potential	
Objective	Reduce the dependency on the grid by 50% through the PV installation, battery storage, and EV chargers.
Evaluation	Data have been monitored for the current situation: PV production and at least 1 charging session of all installed chargers. We compared the data with the pre-PV system data and can validate that the required grid power capacity is lowered by over 50%.
Objective	IMPACT Increase the utilization rate of the generated renewable energy to 60%.
Evaluation	According to monitored data, the use case site is capable of utilizing 60% of generated power with solar charging function.
Objective	V2G chargers could reduce the dependency on the grid with an extra 50% (simulation).
Evaluation	Since V2G is not operational, we have no live data supporting this, but together with SCALE partners we are working on the simulations to validate the hypothesis in the coming period Q1-Q2 2025.

Evaluation Charging services	
AC	At the pilot site we have over 30 V1G AC chargers. We can test smart charging capabilities (such as dynamic load management), we can setup scenarios for different behind the meter optimization. As the CPO of the site we can control the system through our backend and also using Terra Gateway Pro.
DC	Bidirectional charging using DC charger based on ISO15118-2 will be demonstrated. The EMS communicate with the charger through Terra Gateway Pro.

Evaluation Energy Management Services	
The energy management system (EMS) will be developed by EMS and Enervalis in which different goals will be followed.	
1. Primary objective To develop an optimal EMS to reduce the electricity cost of the use case by V2G. This also includes peak load reduction of the use case.	
Evaluation	The demonstrations are ongoing and the results will be evaluated in terms of cost reduction for the different charge scenarios.
2. Secondary objective To develop an optimal EMS to increase the self-consumption of solar PV and hence reduce the carbon emission to get as close as possible to a net zero emission in this use case.	
Evaluation	The demonstrations are ongoing and the results will be evaluated in terms of cost reduction for the different charge scenarios.

Evaluation System architecture	
Control topology	*CPO, EM*
Evaluation	
Communication protocols	*OCPP, OCPI*
Evaluation	



Evaluation of overall pilot results
Communication (interoperability) between systems within the pilot site is key to unlock all the optimisation potential. Success depends not only on hardware elements, but V2G capable vehicles are also needed to successful tests. Without supportive legislation environment V2G cannot spread widely.

2.2.3 B3 Smart Charging in car dealer Depot

Use case lead	**Enedis – Karima BOUKIR**
Context of the use case	The use case takes place at a car park depot in Toulouse, France, where cars are stored and charged before being delivered somewhere else. The V1G charge point is used by the staff to charge EVs that must be charged at about 50% SOC before being delivered (current average is about 10 to 30 EVs per day). The main problem encountered is that no smart charging strategies have been applied, even night shifting is not applied. Up to now, the number of EVs are manageable but as electrification of the car fleet is growing, we need to understand how much power capacity will be requested in mid-term (with and without smart charging option) for this use case.
Description of the use case	The site is already equipped with rooftop solar PV and some V1G chargers are already installed. The need is to analyse the data and define smart charging scenarios to be applied against: local peak reduction, tariffs optimization and local PV synchronization.
The goal of the use case	The main goal, from DSO perspective, is to reduce the needed grid capacity, and thus the grid reinforcement. But as a whole, it is to forecast how much power increase will be needed for this kind of sites which are numerous and get ready for a fair power increase.

Use case scope

The table below presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				B: Smart charging at businesses/ offices
Use case number				B3
Use case				Enedis
Mobility services			Type of service	Company cars
Charging services		AC	Unidirectional	✓
			Bidirectional	
		DC	Unidirectional	
			Bidirectional	
			Fast charging	
Energy services	Local behind-the-meter optimization	Increase self consumption of on-site renewables	V1G	✓
			V2X	
		Reduce demand charges	V1G	✓
			V2X	
		Time-of-Use shifting	V1G	
			V2X	
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	
			V2X	
		Power Quality control	V1G	
			V2X	
System architecture		Control topology	OEM	
			CPO	
			EM	✓
		Communication protocols	EV - Charger	n.a.
			Charger - EMS	OCPP 1.6 (simulated)
			Charger - CPO	n.a.
			CPO - SCSP	n.a.
			CPO - eMSP	n.a.

Evaluation pilot objectives	
Objective	Prevent further grid reinforcements by limiting the needed power capacity.
Evaluation	Data has been monitored for the current situation. Electricity full site load + charging session for one whole week (about 30 EVs per day), only day times were used. Below a figure for on–Site consumption including EV charging sessions (10-30) per day (2023).

<table>
<tr>
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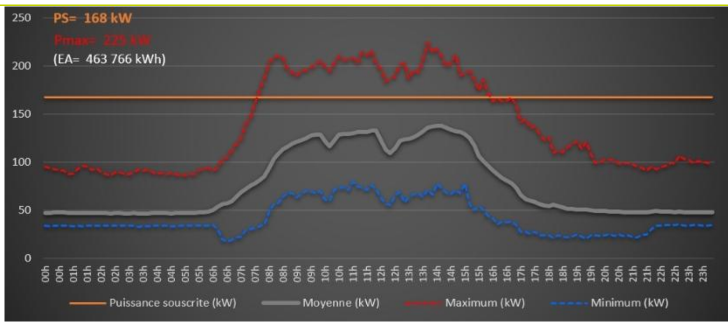

3 scenarios were run: 100 + 30 EVs/day; 250 +30 EVs/day; 500 + 30 EVs/day

The existing profile has been used to model the charging load. Each scenario runs with and without smart charging strategy (using day and night charging sessions).

Here, we forecast future demand by simulating three scenarios for daily electric vehicle (EV) charging fleets. Due to lack of space only 1 scenario is displayed (full analysis includes the 3 major scenarios: 2023+ 100 EVs; 2023 + 250 EVs; 2023+500 EVs). For every scenario, illustrations are displayed: in yellow dumb charging, in green with smart charging. Simulation results indicate that utilizing off-peak charging periods (both day and night) reduces the required power capacity by 50%, compared to maintaining charging exclusively during daytime hours.

Conclusions are that the required grid capacity has been reduced by 50% for the 3 scenarios (as indicated by the green curve instead of yellow, in the figure below).

</td>
</tr>
<tr>
<td>Objective</td>
<td>Finding the optimal charging strategy for self-consumption (through simulation).</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Data have been monitored for the current situation thanks to the EU website for PV generators. The site’s consumption load curve shows that charging sessions are occurring during the daytime, and mostly at lunch break. Given the PV installation of 12 MW and the corresponding EV park (of about 70 kW per charging session for the whole fleet), local generation is almost exclusively feeding the charging sessions. Figure below shows the local PV generation.</td>
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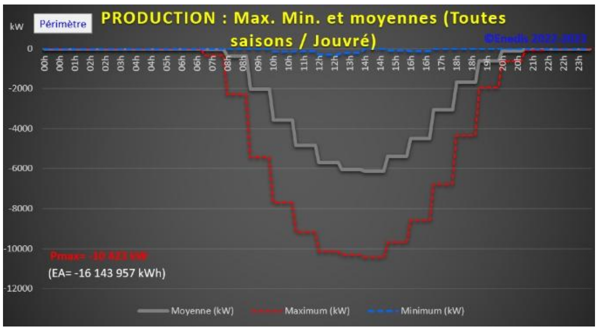
</table>

Evaluation KPIs/ upscaling potential	
Objective	Power peak reduced by 30%.
Evaluation	50% was achieved
Objective	Reduce total power needed.
Evaluation	Total power needed was reduced by 50%
Objective	Reduce costs for charging.
Evaluation	The owner did not share the billing data. This was suggested in the GA, as in France energy prices for high power customer is not public (while for residential it is). The comparison could not be done. But in general for residential there is 30% reduction when opting for ToU (time of use) tariffs.
Objective	Increased share of renewable energy used for charging: 30% in the summer, 10% in the winter.
Evaluation	In both case the share has been increased to > 50 % as the charging sessions are done during the day, and mostly at lunch time, when PV generation is at the maximum.

Evaluation Charging services	
AC	The AC chargers were the existing property of the business owner and were involved in the scenario simulations to evaluate the load profile (used in the simulation) based on 1 week data of EV charging (average of 30 EVs).

Evaluation Energy Management Services	
Optimize the use of available power capacity for charging,	
Evaluation	Conclusions are that the required grid capacity has been reduced by 50% for the 3 scenarios.
Increase used RE influx (simulated as self-consumption site),	
Evaluation	Local generation is almost exclusively feeding the charging sessions.
Shift to lower prices as Time-of-Use tariffs	
Evaluation	This is all up to the site owner when the EV fleet will be more significant.

Evaluation of overall pilot results
Thanks to smart charging by shifting some load to night times, the future needed capacity has **been reduced by 50%** for the 3 scenarios evaluated. However, as the cars needed to be charged each morning (one of the constraints defined in the algorithm), we could not gain more than 50% reduction in capacity.

2.2.4 B4 V2G chargers at office and residential buildings (Gothenburg)

Use case lead	Chalmers - David Steen
Use case context	The use case took place at Chalmers University of Technology, Gothenburg, Sweden. One of the chargers was installed in a living lab where novel energy solutions can be demonstrated and tested and a bidirectional DC was installed at a campus building to demonstrate bidirectional charging. The charger was added into an existing building EMS to assess the potential gain from smart charging and V2G.  Demonstration of bidirectional DC charging at Chalmers Campus
Use case description	The test site was located at Chalmers University Campus in Gothenburg. The AC charger was installed at a smart building called HSB Living Lab, while a DC bidirectional charger was installed in one of Chalmers Campus buildings, to demonstrate V2G functionality in different settings and environments. The HSB LL is a smart residential building equipped with rooftop solar PV, stationary battery energy storage, and some controllable loads. Due to the limited number EVs compatible with AC bidirectional charging, V1G smart charging was mainly demonstrated at the site. The V2G-ready DC charge station was installed in the power system laboratory at Chalmers campus testbed. The testbed is operated by *Akademiska hus,* the owner of the buildings and energy infrastructure at Chalmers Campus. The testbed enables researchers to perform real life demonstration in a controlled environment.

	Due to the lack of public V2G compatible EVs, the use case was foremost focused on demonstrating the V2G functionality using a Polestar 2 EV.
Use case goal	The main goals with this use case were the following: • To increase the self-consumption of the on site solar PV through V1G and V2G technology. Since the demonstrations was conducted during the autumn and winter the PV production did never exceed the demand of the building during the evaluation phase. Instead demonstration was focusing on reducing the charge cost and peak demand, • Reduction of the electricity bills for the building was another important goal to be achieved in this use case. This was also set as the objective function of the optimization algorithm used. In this scenario, the EV was charged at off-peak time when the electricity price was low and discharged at peak times when the electricity price was high. • Reduction of peak power was another goal, and by incorporating power tariffs into the objective function the peak load was also reduced by the optimization algorithm.• The battery degradation of EV’s battery for discharging through V2G technology has been a large concern for V2G. One goal was to incorporate battery aging in the cost function in order to determine if it is economic to discharge the EV and how it would affect the optimal charge/discharge pattern of an EV. • The demonstrations were conducted following a modification of the ISO standard 15118-2 as a first step towards a full integration of the 15118-20 standard for the V2G communication.  Smart charging at HSB Living Lab

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				B: Smart charging at businesses/ offices
Use case number				B4
Use case				Chalmers
Mobility services			Type of service	Company car
Charging services		AC	Unidirectional	✓
			Bidirectional	
		DC	Unidirectional	
			Bidirectional	✓
			Fast charging	
Energy services	Local behind-the-meter optimization	Increase self consumption of on-site renewables	V1G	✓
			V2X	✓
		Reduce demand charges	V1G	✓
			V2X	✓
		Time-of-Use shifting	V1G	
			V2X	
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	✓
			V2X	✓
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	
			V2X	✓
		Power Quality control	V1G	
			V2X	
System architecture		Control topology	OEM	
			CPO	
			EM	✓
		Communication protocols	EV - Charger	ISO 15118-2 / ISO 15118-20
			Charger -EMS	OCPP 1.6
			Charger -CPO	n.a.
			CPO - SCSP	n.a.
			CPO - eMSP	n.a.

Evaluation pilot objectives	
Objective	Interoperable charging points through implementing ISO15118-20.
Evaluation	The part of the ISO15118-20 related to bidirectional charging has been implemented on top of the ISO15118-2. This has been demonstrated using a DC bidirectional charger.
Objective	Increase grid flexibility by delivering power back to the DSO via V2G capabilities.
Evaluation	The flexibility provision through V2G was calculated in the scheduling algorithm and was compared to the case with V1G. The results from the scheduling algorithm showed that the value from flexibility provision increased substantially, especially when symmetrical frequency response services were provided.
Objective	Reduce costs via peak shaving and demand charge reduction.
Evaluation	The cost reduction through V2G was calculated in the scheduling algorithm and was compared to the case with V1G. The results from the scheduling algorithm showed that although the total cost could be reduced for the user, V2G could lead to higher peak demand, although the peak demand occur during night hours when demand was generally lower. The results depend to large extend on the peak demand tariff considered.

Evaluation KPIs/ upscaling potential	
Objective	Contribute to production ready V2X capable cars (before 2025).
Evaluation	Through the project, Polestar has been able to work intensively to reach the goal of having production ready V2X cars.
Objective	Results and environmental savings directly contributing to Global Reporting Initiative (GRI).
Evaluation	The results from the project can be used to estimate the environmental savings achieved from V2G services. These numbers can then be used as basis for reporting e.g. reduction of GHG emissions (GRI 305-5).

Evaluation Charging services	
AC	Unidirectional smart charging using AC chargers has been demonstrated. A backend based on OCPP 1.6 with extension for V2G was developed and utilized together with an EMS and a web-based front-end application to get the user preferences.
DC	Bidirectional charging using DC charger based on ISO15118-2 has been demonstrated. The EMS communicate with the charger through MQTT commands and through OCPP1.6.

Evaluation Energy Management Services
An EMS developed by Chalmers was used and connected to the chargers through both OCPP1.6 and MQTT protocol. The EMS includes a scheduling algorithm where different objectives such as cost or CO2 emissions could be minimized. Using a web-based user interface, the user selected his/her preferences and started the charging session.
1. Primary objective To develop an optimal EMS to reduce the electricity cost of the use case by smart charging and V2G. This also includes peak load reduction of the use case.

Evaluation	The demonstrations showed that from the smart charging sessions a possible cost reduction by 19,8% could be achieved while reducing the CO2 emission by 1,3% (based on electricity maps energy mix for Sweden (area3)). The main part of the savings was achieved by reducing the peak demand but also due to reduced charging during hours with high electricity prices. Due to the limited availability of V2G compliant EVs, the bidirectional demonstration focused on showing that the charging could be controlled from the EMS and less on the monetary savings. For the monetary savings a comparison between smart charging and V2G was conducted using the developed scheduling algorithm used in the EMS. From the simulations the savings was found to vary greatly depending on the simulated year (due to difference in spot price) as well as if the user participated in frequency reserve markets or not. As an example, the possible annual savings from V2G (compared to smart charging) for a small house with EV was in 2022 34% while the savings was found to be 7% in 2024 for the same house.
2. Secondary objective To develop an optimal EMS to increase the self-consumption of solar PV and hence reduce the carbon emission to get as close as possible to a net zero emission in this use case.	
Evaluation	The demonstrations showed that from the smart charging session it was possible to reduce the CO_2 emission by 3,6% (based on electricity maps energy mix for Sweden (area3)) if the user decides to charge according to the CO_2 emission reduction alternative. When it comes to self-consumption of PV, the building at the demonstration site was not exporting any PV production during the demonstration phase, hence this has not been evaluated.

Evaluation System architecture	
Control topology	*Energy Management*
Evaluation	An interface was developed and used to provide user input to a scheduling algorithm. The scheduling algorithm then dispatched the setpoints to the charger.
Communication protocols	*ISO15118-2 with extension*
Evaluation	The ISO15118-2 standard with extension was implemented to communicate between EV and CP for AC and DC charging. For the DC charging the charging/discharging session was functioning. For AC charging the charging session was functioning.
Communication protocols	*OCPP1.6*
Evaluation	The OCPP1.6 protocol with extension (based on OCPP2.01) was developed to conduct charging and discharging by sending charge profiles. For AC charging the charging control was successfully demonstrated, while the discharging was not demonstrated due to lack of compatible EVs. For the DC charging, alterations in the OCPP1.6 were not possible in the charge controller and hence the demonstrations were conducted using MQTT commands sent directly to the charger.

Evaluation of overall pilot results
The key take aways from the demonstrations can be listed as: 1. V2G can increase the potential flexibility provision from EVs substantially. 2. Monetary evaluation is dependent on the electricity cost and tariff design making it difficult to evaluate the economic value of V2G and smart charging. 3. Peak demand may increase locally for V2G charging but is generally transferred to off-peak hours. 4. V2G using DC charger was found easier to implement compared to AC. 5. Communication over OCPP2.0.1 was found challenging and require close collaboration between the charge station provider, the CPO and CMS.

2.3 Innovation cluster C: Smart charging of light and heavy-duty fleets

In this innovation cluster smart charging and V2X takes place in the context of light and heavy duty fleets, typically located at depots. Heavy duty vehicles require larger batteries and thus longer charging times. Because these are often commercially exploited vehicles, their utilization rate (effective time for which they are on the road) is essential. Adding to this how crucial charging power is to, SCALE will address this by implementing a charging solution with local battery storage to increase charging speeds without costly grid reinforcements. Furthermore, cost reductions can be achieved through SCALE's solutions utilizing smart charging and V2X services to enable load balancing services and reduce peak loads on the power system.

2.3.1 C1 Station-based Serviced Office B2B car-sharing with demand side management (Smart charging EVs + Building energy demand)

Use case lead	**CURRENT - Åsmund Frengstad**
Use case context	The use case takes place in Lørenskog, Norway. The challenge is operational cost for client (HQ of Norway's biggest car dealership) By reducing peak power, optimize charging according to Spot market price and usability. They would like to showcase the vehicles capabilities of V2G (KIA) and see how their car sharing fleet can benefit from Smart Charging and V2G. As well as gaining insight in how to align their business with the change to electric drive trains. The initial venue for the pilot was supposed to be at a garage on University of Oslo, due to change of contract on parking operator the site was changed, to a parking/commercial real estate area outside Oslo, with car sharing, and close proximity to a large residential area.
Use case description	The pilot site is the HQ of one of Norway's largest Car dealerships and importers of cars. They are looking into new business models with the emerging E-mobility market. At the site there are 3 different dealerships, a car sharing service as well as service garages. By applying Smart Charging and V2G, the charging plaza should lower the peak max, and the load curve should align (inverted) with local production and energy prices. Also, there is an opportunity to assess V2G potential business and energy gains with the existing AC

	connected vehicles present on the site. The location is placed in the vicinity of larger residential areas and is not used a lot outside of office hours.
Use case goal	The primary goal of this use case is to optimize the economic and operational efficiency of EV charging infrastructure through innovative energy management strategies and business model development. The objectives are: • **Reducing Grid Fees with Smart Charging** By implementing intelligent, data-driven charging strategies, the system aims to shift EV charging to periods with lower grid fees. This approach minimizes peak load contributions and utilizes demand-response signals to align charging schedules with grid capacity and pricing, resulting in cost savings for both EV owners and operators. • **Generating Revenue from Flexibility with Smart Charging** Leveraging unidirectional Smart Charging capabilities, the system will participate in flexibility markets by adjusting charging patterns in response to grid needs. This ensures efficient use of energy resources while creating a new revenue stream for charging operators. By enabling a seamless integration with energy markets, the project maximizes value extraction from flexibility services. • **Establishing a Viable Business Model for Vehicle-to-Grid (V2G)** The project aims to develop a business model that includes EV drivers as active participants in the V2G ecosystem. By addressing technical, economic, and regulatory challenges, the model seeks to incentivize drivers to provide grid services through their EVs. This will ensure that drivers are fairly compensated for their contributions while enhancing the resilience and stability of the energy grid. • This use case focuses on demonstrating how these strategies can be implemented in real-world scenarios to deliver mutual benefits for energy stakeholders, charging operators, and EV drivers

Use case scope

The table below presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For a complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				**C: Smart charging of light and heavy-duty fleets**
Use case number				**C1**
Use case				**Current**
Mobility services			Type of service	Private & company cars
Charging services		AC	Unidirectional	✓
			Bidirectional	
		DC	Unidirectional	✓
			Bidirectional	✓
			Fast charging	
Energy services	**Local behind-the-meter optimization**	Increase self consumption of on-site renewables	V1G	
			V2X	
		Reduce demand charges	V1G	✓
			V2X	✓
		Time-of-Use shifting	V1G	✓
			V2X	✓
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	✓
			V2X	✓
		Intraday portfolio optimization	V1G	✓
			V2X	✓
	System balance	FCR	V1G	✓
			V2X	✓
		aFRR	V1G	✓
			V2X	✓
		mFRR	V1G	✓
			V2X	✓
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	✓
			V2X	✓
		Short term congestion management	V1G	✓
			V2X	✓
		Operational congestion management (near real-time)	V1G	✓
			V2X	✓
		Power Quality control	V1G	✓
			V2X	✓
System architecture		**Control topology**	OEM	
			CPO	✓
			EM	
		Communication protocols	EV - Charger	ISO 15118-2 / ISO 15118-20
			Charger -EMS	OCPP 1.6-2.1
			Charger -CPO	OCPP 1.6-2.1
			CPO - SCSP	OCPI 2.2
			CPO - eMSP	OCPI 2.2

Evaluation pilot objectives	
Objective	Reduce complexity for the driver for billing & authorization (plug & charge).
Evaluation	Currently, our chargers do not support ISO 15118-3 autocharge or -20, making Plug & Charge unavailable. To compensate for this, we've fully implemented the new AFIR regulations and tested automated license plate recognition to deliver a comparable user experience.
Objective	Increase usability by integrating the control mechanism interface with the fleet management system.
Evaluation	By providing fleet operators and users with real-time data, we've successfully enhanced usability. However, limited access to data via ISO 15118 has prevented direct data retrieval, prompting us to use alternative methods, such as insights gathered from the end-user app, to access fleet information.
Objective	Ensure interoperability through ISO15118-20.
Evaluation	Current has made significant strides towards ensuring interoperability through ISO 15118-20 by implementing and achieving certification for OCPP 2.0.1 and OCPI 2.2.1. This positions our Charging Point Management System (CPMS) to handle ISO 15118-3 and 20 functionalities. However, our chargers currently do not support ISO 15118-3 Autocharge or ISO 15118-20, rendering Plug & Charge unavailable. While we have successfully implemented Autocharge at several DC locations, we have yet to complete a successful interoperability test for ISO 15118-20 at a pilot site. To compensate for these limitations, we have fully implemented the new AFIR regulations and tested automated license plate recognition, providing a comparable user experience.
Objective	Reduce cost by demand charge reduction & avoiding grid reinforcements.
Evaluation	By introducing smart charging and queues in fixed periods (time, date) according to historical charging data and consumption from buildings. We have reduced peak cost, and managed to increase capacity (amount of chargers) without any need for grid reinforcement, see: ***Project start*** • *102 charge points* • *Max peak 523 KW* ***January 2025*** • *201 Charge Points* • *Max peak 400 KW* Moreover, there is considerable room for further optimalisation as the current operation is lacking the customer SoC or departure time and these limits are also designed to avoid customer complaints.

Evaluation KPIs/ upscaling potential	
Objective	Impact potential: until 2025 all vehicles to be electrified (900 delivery trucks, 100 long-haulers, 2000 delivery vans).
Evaluation	Due to a location change this KPI can no longer be evaluated as it was specifically linked to the fleet of the previous location. However, although the infrastructure falls outside of the project, during the SCALE time-frame the facility has increased to 20 Charge Points as well as 3 High power DC stations which have been added to the location.
Objective	Higher utilization of charge point considering control signals like off-peak hours & low tariffs
Evaluation	We have an increased usage from the start of pilot, and have identified how to reduce costs for EV drivers whilst increasing utilization by applying smart charging (unidirectional)
Objective	Results and environmental savings directly contributing to Global Reporting Initiative (GRI).
Evaluation	685 Kg CO_2 emissions is saved

Evaluation Charging services	
AC	The AC smart charging has been and will be just unidirectional. the AC chargers planned for bidirectional was not delivered with functionality and supplier went bankrupt. thus only unidirectional charging over AC
DC	The DC charger is, from a firmware point of view, not capable to do V2G yet, thus not applied in use case yet.

<table>
<tr><th colspan="2">Evaluation Energy Management Services</th></tr>
<tr><td colspan="2">1. Primary objective
a. Reduce cost
b. Increase range of operative service, within the physical boundaries</td></tr>
<tr><td>Evaluation</td><td>We have successfully increased the energy delivered while reducing the cost per kWh delivered to EV drivers</td></tr>
<tr><td colspan="2">2. Secondary objective
a. Create secondary revenue stream by applying flexibility from the site.</td></tr>
<tr><td>Evaluation</td><td>Current Status: The project is waiting to apply flexibility from the site to generate a secondary revenue stream. The context in which this will be applied is as follows:

o Flexibility in this context refers to the ability to manage energy usage dynamically across different assets (such as charging stations, building systems, or energy storage systems). This could be used to participate in demand response programs or energy markets, offering opportunities to generate revenue by optimizing energy consumption and production based on real-time market prices or grid needs.

o The concept of a secondary revenue stream usually involves monetizing unused or underutilized resources, such as energy flexibility, which can be sold back to the grid or used to reduce operational costs. By shifting energy demand (e.g., charging EVs during off-peak hours or discharging storage systems during peak times), the site could generate additional income through participation in flexibility markets.

Conclusion:
The objective of creating a secondary revenue stream by applying flexibility from the site is feasible but still in progress. While the concept of flexibility is sound and can lead to additional revenue through demand response, V2G services, or other energy markets, the project must first implement a system for flexibility management and ensure the infrastructure is capable of participating in these markets. The next steps should involve technological deployment, market exploration, and system integration to capture the value of flexibility and transform it into a viable and profitable secondary revenue stream.</td></tr>
</table>

Evaluation System architecture	
Control topology	*CPO*
Evaluation	Project Topology Overview: The focus of the CPO is on the charging interface and its connection to the energy system, while the integration with car systems and building systems remains a secondary consideration. **CPO's Primary Focus on Charging Interface** Strengths: The CPO's focus on the charging interface and energy system is essential for ensuring that the charging stations operate efficiently with the power grid. This core functionality is vital for basic operation, ensuring compatibility with the energy market, and offering customers a reliable and effective charging experience. Challenges: By not integrating with car systems (such as utilizing vehicle data for optimized charging or offering features like plug-and-charge via ISO 15118) or building systems (such as energy management and dynamic load balancing), the CPO is missing an opportunity to leverage data for more efficient, cost-effective, and intelligent charging strategies.- Without these integrations, the full potential of smart charging (including dynamic load balancing, charging prioritization, and optimization based on real-time building energy needs) cannot be realized. **Car System Integration** Benefits of Integration: - Integrating with the car system (through protocols like ISO 15118) allows for real-time data exchange, enhancing charging algorithms with vehicle-specific information (e.g., battery status, charging preferences, etc.). - Enables plug-and-charge functionality, streamlining the user experience by eliminating the need for manual authentication. - Better optimization of charging times and energy consumption based on the vehicle's real-time energy requirements can lead to lower operational costs and improved energy efficiency. Current Limitation: - Without access to car system data, charging operations remain disconnected from the vehicle's actual needs, leading to inefficiencies such as overcharging, long wait times, or suboptimal charging schedules. **Building System Integration** Benefits of Integration: - Integrating the charging system with the Building Energy Management System (BEMS) enables dynamic load balancing, ensuring that energy consumption from the chargers is optimized with respect to overall building demand.

	- The integration allows for peak shaving, reduced grid fees, and more efficient energy use, as charging can be adjusted in real-time based on building energy demand, grid conditions, and pricing. - The ability to synchronize with renewable energy sources (such as solar panels or energy storage) can further reduce operational costs and make the building more energy-efficient. Current Limitation: - With the CPO not focusing on integration with the building system, these benefits cannot be realized fully. Charging is likely treated as a stand-alone system, disconnected from the broader building's energy needs, leading to missed opportunities for energy savings and cost reduction. Challenges: - The lack of integration between the CPO, car systems, and building systems creates a fragmented topology. This limits the scalability and adaptability of the charging infrastructure, as it cannot respond to evolving energy markets, customer needs, or building requirements in a coordinated and dynamic manner. - The focus on energy system connection alone could result in higher operational costs, less efficient charging, and a poorer user experience, as vehicles and building systems are not fully considered in the optimization process. **Opportunities for Improvement** - Enhanced Data Utilization: By integrating with car systems, the CPO could leverage vehicle-specific data to optimize charging, such as adjusting charging rates based on battery levels, vehicle schedules, or driver preferences. - Holistic Energy Management: Integration with the building's EMS could allow for the dynamic balancing of charging loads with other energy demands, reducing the building's energy consumption and overall operational costs. This also opens the door to leveraging demand response programs or participating in flexibility markets for additional revenue streams. - Future-Proofing the System: With the increasing adoption of electric vehicles (EVs) and smart grids, the ability to integrate car systems and building systems into the charging infrastructure will be crucial for long-term viability. The current focus on just the energy system may work in the short term but could fall behind as these markets and technologies evolve. **Conclusion:** While the current focus on the charging interface and energy system provides a solid foundation for the CPO's role, the lack of integration with car and building systems limits the potential for smart charging and cost optimization. Integrating the CPO with vehicle data and building energy systems will enable dynamic load balancing, improve energy efficiency, and create a more cost-effective and user-friendly charging experience.

Communication protocols	*OCPP, OCPI*
Evaluation	OCPP and OCPI are successfully utilized for communication with charging stations and car-sharing systems, respectively. There is a need for standardized communication with fleet management systems and building systems to further optimize the charging infrastructure and its integration. **OCPP (Open Charge Point Protocol)** o Successes: § Interoperability: OCPP is a widely adopted protocol for communication between charging stations (CPOs) and backend systems. It enables flexibility in choosing different charging station hardware and software without vendor lock-in. § Real-time Communication: OCPP supports real-time monitoring and control of charging stations, including status updates, power usage, and fault detection. § Scalability: OCPP allows easy scaling of the charging network, which is essential for growing fleets and infrastructure. o Effectiveness: § OCPP effectively meets the needs of smart charging, ensuring the seamless exchange of data between the charging station and the energy system. § Potential Improvement: As OCPP primarily focuses on the connection between the charger and backend energy management system, its integration with building management and fleet systems requires additional layers (e.g., custom middleware) for full optimization. **OCPI (Open Charge Point Interface)** o Successes: § Interoperability with Car-Sharing Systems: OCPI facilitates the communication between charging stations and car-sharing systems, allowing for efficient data exchange on vehicle availability, billing, and charging session status. § Dynamic Charging Cost Management: By integrating with car-sharing platforms, OCPI enables the adjustment of pricing models for energy usage, ensuring cost-effective operations. o Effectiveness: § OCPI has shown positive results in managing EV charging in car-sharing operations, contributing to flexible pricing and scheduling. § Potential Limitation: Like OCPP, OCPI primarily addresses communication with car-sharing systems and doesn't fully integrate with fleet management systems or building energy systems. Need for Standardized Communication with Fleet Management Systems: o Current Gaps: § Fleet management systems typically manage large fleets of vehicles, and the ability to synchronize charging schedules, vehicle availability, and

	energy consumption is crucial. However, no standardized communication protocol currently exists for seamless integration between CPOs and fleet management systems. o Benefits of Standardization: § A standardized protocol would enable fleet operators to efficiently manage their fleets, optimizing vehicle charging based on energy availability, fleet schedules, and operational needs. § Improved fleet scheduling and maintenance management can enhance fleet performance and reduce operational costs by aligning charging schedules with fleet use. § A unified system would reduce the need for custom integrations and increase system scalability. **Need for Standardized Communication with Building Systems (EMS)** o Current Gaps: § Communication between the charging infrastructure and building energy management systems (EMS) remains fragmented. The charging network typically operates in isolation, without real-time optimization of energy use across the entire building. o Benefits of Standardization: § Integrating charging infrastructure with the building EMS via standardized protocols enables dynamic load balancing, ensuring that charging does not cause peak demand spikes or interfere with other critical building operations (HVAC, lighting, etc.). § Communication with building systems allows for optimized energy usage, improving cost efficiency, grid stability, and the ability to participate in demand response programs. o Challenges: § Different building systems use a variety of communication standards (e.g., KNX, BACnet, Modbus, etc.), making integration complex. § A unified or standardized protocol that bridges these various systems is essential for achieving a seamless integration that maximizes energy efficiency across both the building and the charging infrastructure. **Recommendations for Standardized Communication** Explore Existing Protocols for Fleet Management Integration: o Consider leveraging existing standards such as ISO 15118 (for EV-to-grid communication) or V2G (Vehicle-to-Grid) communication protocols. While these are still developing, they may provide a foundation for integrating fleet management and charging systems. o Additionally, protocols like AMQP or MQTT could be explored for real-time messaging between charging stations, fleet management, and car systems. Develop or Adopt Standardized Protocols for Building System Integration:

	o KNX, BACnet, and Modbus are widely used in building systems, and AMQP could serve as a bridge for standardizing communication between these systems and the charging infrastructure. o OpenADR (Open Automated Demand Response) could be another useful protocol for managing grid interactions and balancing load between charging stations and building systems. o Create or adopt middleware that can translate between protocols used by the charging system and building EMS to facilitate smooth data exchange. **Middleware Layer to Bridge Gaps** o Implement a middleware solution that can communicate with both OCPP/OCPI systems and the various protocols used in fleet and building management. This would reduce the complexity of implementing new protocols and improve interoperability. Work with Industry Standards Bodies: o Engage with industry standardization groups (e.g., IEC, ISO) to advocate for more robust and interoperable protocols that can cover the needs of charging systems, fleet management, and building energy management. **Conclusion** The current use of OCPP and OCPI works well for managing charging stations and car-sharing systems but leaves gaps in communication with fleet management systems and building energy systems. There is a clear need for standardized communication protocols to improve interoperability across these systems, enabling dynamic load balancing, optimized fleet operations, and energy efficiency. Exploring existing standards, such as ISO 15118, V2G, and AMQP, while also considering the development of new protocols or middleware solutions, can provide the foundation for a more integrated, cost-efficient system.

Evaluation of overall pilot results
The pilot is showing promising progress despite implementation and compliance issues. The findings so far indicate that the overall concept is sound, but technical challenges related to flexibility management, V2G integration, and compliance need to be addressed for the system to function optimally. The next steps should focus on resolving the firmware and system integration issues, testing the flexibility and V2G functionality, and ensuring that these innovations translate into upstream revenue streams and financial sustainability.

2.3.2 C2 Highway charging with local generation & storage (Eindhoven)

For this use case preparation VDL has been working on the upgrade of the charging infrastructure on the 'VDL charging square'. Work carried out has full overlap with the C3 Virtual power plant (VPP) with renewable energy generation and second life battery storage.

Use case lead	**VDL - Ruud Bouwman**
Use case context	VDL DC Charging Test Centre Valkenswaard, greater Eindhoven region, The Netherlands reaching carbon neutrality in road freight- and passenger transport zero emission vehicles are the backbone to meet these goals. Next to Electric public transport buses these kind of EV vehicles starting to hit the market. Today the charging infrastructure that is indispensable to operate heavy duty EV's on the European highways is almost complete missing and not adapted to the specific needs, power demands and sizes of parking spaces of these types of sustainable transport. Doing simulations is a convenient way to investigate improvements for the charging infrastructure. Heavy Duty EV's are business tools run by professional transport operators so reducing charging time and (on-line) pre booking services as part of their Fleet management systems are essential for a correct trip planning and to avoid high operational costs. The need to investigate the desired infrastructure is to support the electrification of the long-haul transport vehicles by minimizing the grid peak load.
Use case description	Simulating the optimal set up for highway DC High Power charging for long haul E coaches and other heavy duty EV's. The implemented charging schedule is based on typical coach driver schedules for day and overnight driving and the charger powers. Smart-charging is not considered, while this is not applicable due to the nature of stop time of the vehicles. Based on this demand, the optimal setup is obtained from a simulation model, which estimates the optimal BESS capacity, grid connection and allows optimal operation in terms of operational costs.
Use case goal	The goal is to obtain an optimal setup of a highway charging station based on location constraints in order to supply sufficient amount of charging power compliant to the needs of the long-haul vehicle operators by performing simulations. At the same time, steering on expenses saved on grid reinforcements while increasing charging power which can also be used as opportunity charging for heavy duty applications. As a result, the grid connection needed for a desired load request is estimated while keeping the operational costs to a minimum (i.e. the costs spent on the grid peak power and grid energy).

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				C: Smart charging of light and heavy-duty fleets
Use case number				C2
Use case				VDL
Mobility services			Type of service	B2B
Charging services		AC	Unidirectional	
			Bidirectional	
		DC	Unidirectional	✓
			Bidirectional	
			Fast charging	✓
Energy services	Local behind-the-meter optimization	Increase self consumption of on-site renewables	V1G	
			V2X	
		Reduce demand charges	V1G	✓
			V2X	
		Time-of-Use shifting	V1G	
			V2X	
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	
			V2X	
		Power Quality control	V1G	
			V2X	
System architecture		Control topology	OEM	
			CPO	
			EM	✓
		Communication protocols	EV - Charger	n.a.
			Charger -EMS	n.a.
			Charger -CPO	n.a.
			CPO - SCSP	n.a.
			CPO - eMSP	n.a.

Evaluation pilot objectives	
Objective	Finding optimal setup of future highway high power charging infrastructure for heavy duty vehicles through simulation. Considering customer expectations, charging on demand, predicted (dynamic) charging time and pre booking.
Evaluation	Physical implementation was limited due to the BESS not being operational within this project. Additional limitations are that there are no e-coaches in the market. The performance of e-coaches will be very different from the current diesel fleets and is therefore unknown. As a result, we assume that the energy infrastructure around the highway charging hub can be modelled for this use case. There is currently no heavy duty network available to use in this definition, except for the chargers we know from the charging hub that are going to be used in the model. VDL has developed an energy model which uses data recorded from the Valkenswaard site to determine an optimal setup of the solar panels and BESS for highway charging in terms of operational costs. Using this model, the optimal setup of the BESS is determined for a fixed predefined charging booking schedule and a predefined maximum peak grid power to minimize operational costs. The fixed predefined charging booking schedule is based on customer expectations, namely the resting times of the drivers and therefore the charging slots are pre-booked and defined. To complete the simulation, this booking schedule is fixed during the simulation time and therefore no dynamic booking services have been implemented. The charging booking schedule can easily be adapted to a different schedule. As a result, in a future iteration when we have a predefined booking schedule, we rapidly provide optimal operation of the network and related grid connections parameters to alleviate costs and grid load.
Objective	Increase charging power without grid reinforcements through stationary batteries.
Evaluation	Whilst we can use the model to size the components of the energy network while minimizing the grid energy and grid peak power costs heavy duty highway charging infrastructure is currently not existing and as such there was no reference case to be considered. However, we have investigated a relation between the investment costs of energy network components (solar and BESS), the grid power connection costs and energy prices and this already provides building blocks to reach this ambition. Hereby the model is a strong foundation for realising the objective.

Evaluation KPIs/ upscaling potential	
Objective	Expenses saved on grid reinforcements while increasing charging power can be used at all opportunity charging for heavy duty.
Evaluation	The grid connection is modelled in the energy model. Using the model, we have decreased the grid power by adding solar panels and a BESS to the network and have therefore saved on grid expenses. The charging power

	capacity is freely configurable in our model, which allows us to assess all kinds of scenario's.
Objective	Pre booking analysis can increase uptake of long-haul electric heavy-duty vehicle through secured charging places and speeds.
Evaluation	In the energy model no ad hoc charging is considered. All charging events (time and energy demand) in the model are defined. Pre booking is assumed to be essential. Customer route information is not available, so many other assumptions are made on the charging stop frequency and duration.

Evaluation Charging services	
DC	No tests are performed with hardware was not available or suited for smart-charging.

Evaluation Energy Management Services	
Only local energy management on the VDL Charging Test Centre. Optimise self-use of available local onsite solar energy on depots/ minimize use of grid during test charging sessions and store- and recover energy (V2BESS and BESS2V) during charging- or battery high voltage test on EV vehicles. Reduce CO2 footprint of the test facility.	
Evaluation	The integration of the EMS has succeeded in local energy measurement and real time energy data representation. By using a local area network, two of the 5 chargers and the battery system were connected. The EMS aims to control 2 chargers (Heliox and ABB). Unfortunately, the BESS and the 3 Siemens chargers were not repairable within the scope of the SCALE project and for this reasons testing with simulations was necessary. The energy use and generation on site is known and will be used as input for balancing optimization in simulations. Since the hardware support was not arranged in time, the implementation of the EMS on the hardware was not completed and therefore it was necessary to perform simulations to obtain the results. In the simulations, the behind the meter optimization is done. Hypothetical values were used for the grid connection, virtual battery storage to reduce peak power and costs. When there is more solar energy available, the resulting charging power is increased without increasing grid dependency. Further testing will be carried out in January 2025. The scope of the testing is to integrate and control the ABB charger with the Terra Gateway Pro and tests will be conducted on it in cooperation with Enervalis.

Evaluation System architecture	
Control topology	*n/a*
Evaluation	On a high level, for each moment in time there is an energy optimisation carried out for the overall system, which will be the input for the controller of each separate component. Indeed, there is a hierarchy and priorities configured to limiting factors such as price of (avoided) energy price peaks, high load demand.
Communication protocols	*n/a*
Evaluation	Protocols are not used in the energy model. Used on site protocols were outdated and did not support V2x. Supplier support for updating was lacking.

Evaluation of overall pilot results
Communication between systems within the pilot site is key. Equipment needs to have service contracts to ensure operation throughout project/lifetime Vehicle systems need to be included for an effective energy system We can optimally size the energy network components (solar and BESS) of a highway charging station while keeping the grid connection to a minimum using the developed model. The grid peak power can be significantly reduced by using a BESS system.

2.3.3 C3 VPP with renewable energy generation and second life battery storage (Eindhoven)

Use case lead	**VDL - Ruud Bouwman**
Use case context	Given the already significant load on the electrical grid in the Netherlands, implementing a VPP at charging depots is essential to manage energy demand efficiently, reduce grid strain, and ensure a stable and reliable power supply. This can be realized through smart charging, V2X technology, BESS, and the integration of renewable energy sources like solar power, which will reduce grid load and minimize operational costs. The charging test centre in Valkenswaard is not a state-of-the-art latest technology and is therefore only used as a reference to perform simulations. Hardware tests are done independently from the performed simulations.
Use case description	A model is created to simulate how we can optimize the energy flow and grid peak load of the reference test centre using real recorded data from the test site and real operator fleet data by applying smart-charging and a BESS. For the BESS, second life batteries are used from the electric city buses in order to optimally use all components that are available.
Use case goal	The goal is to create a model to simulate how the grid dependency and operational costs can be reduced by applying smart-charging and by using a BESS system and renewable energy.

Use case scope
The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				**C: Smart charging of light and heavy-duty fleets**
Use case number				**C3**
Use case				**VDL**
Mobility services			Type of service	B2B
Charging services		AC	Unidirectional	
			Bidirectional	
		DC	Unidirectional	✓
			Bidirectional	✓
			Fast charging	✓
Energy services	**Local behind-the-meter optimization**	Increase self consumption of on-site renewables	V1G	
			V2X	
		Reduce demand charges	V1G	✓
			V2X	✓
		Time-of-Use shifting	V1G	✓
			V2X	✓
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	✓
			V2X	✓
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	
			V2X	
		Power Quality control	V1G	
			V2X	
System architecture		**Control topology**	OEM	
			CPO	
			EM	✓
		Communication protocols	EV - Charger	n.a.
			Charger -EMS	n.a.
			Charger -CPO	n.a.
			CPO - SCSP	n.a.
			CPO - eMSP	n.a.

Evaluation pilot objectives	
Objective	Reduce costs by being independent (less dependent) of the grid, enabled by a virtual power plant with renewable energy generation, local battery storage and smart charging and V2X. This reduces costs by increased utilization rate of renewable energy generated and by giving used battery packs a second life as stationary storage.
Evaluation	Using the simulation model, we can reduce the operational costs by making use of a second life BESS and uni- and bi-directional smart-charging strategies, based on real data from a fleet operator. This has allowed us to significantly reduce the grid peak power while minimizing the operational costs as well. Reducing the grid peak power is necessary when considering the grid congestion and the high power demands of different sizes of charging depots.

Evaluation KPIs/ upscaling potential	
Objective	Virtual power plant with full energy neutrality
Evaluation	Energy neutrality can be obtained by increasing the number of solar panels. However, since we would need a large setup of solar panels when considering the charging needs of an average bus fleet, this is not feasible to do, since there is not enough space to construct these solar panels. Therefore the focus was more directed towards reducing grid peak power. It is possible to consider additional solar or wind energy generation in the model though, as well as seasonal storage in the form of hydrogen in order to reach energy neutrality.
Objective	100% grid reduction
Evaluation	Using the model, a grid reduction is achieved. However, 100% grid reduction is not feasible when considering an average bus fleet and therefore is not feasible with only solar panels. The evaluation mentioned above holds for this explanation as well.

Evaluation Charging services	
DC	No hardware is tested due to the non-compliance in current software versions of the installed chargers. Conventional, uni- and bi-directional DC smart-charging is considered in the simulation. Uni-directional DC smart charging allows a significant grid peak reduction over conventional charging. The difference between uni- and bi-directional smart charging on the grid peak load is minor.

Evaluation Energy Management Services	
Only local energy management on the VDL Charging Test Centre. Optimise self-use of available local onsite solar energy on depots/ minimize use of grid during test charging sessions and store- and recover energy (V2BESS and BESS2V) during charging- or battery high voltage test on EV vehicles. Reduce CO2 footprint of the test facility.	
Evaluation	V2BESS was not tested as the VDL Bus charging system is not equipped for this and VDL ETS had no influence on the implementation timeline. CO2 footprint has been somewhat reduced by optimizing the energy flow to and from different components.

Evaluation System architecture	
Control topology	*n/a*
Evaluation	Implementation is not carried out, but the concept would be as follows: Ata high level, at a specific frequency, there is an energy optimisation carried out for the overall system, which will be the input for the controller of each separate component. There is a hierarchy and priorities configured to limiting factors such as price of (avoided) energy price peaks and a high load demand.
Communication protocols	*n/a*
Evaluation	Protocols are not used in the energy model. Used on site protocols were outdated and did not support V2x. Supplier support for updating was lacking.

Evaluation of overall pilot results
The energy model can be used to scale all relevant charging site components. The energy system control algorithms data can be generated by the VDL energy model. The energy model can easily be expanded to different energy sources and technologies, for example long term energy storage systems such as hydrogen, synthetic fuels, etc. The grid peak power can be significantly reduced by applying smart-charging and using a BESS system. Considering the high load demand of charging the busses, results are showing that energy neutrality and grid independence will be hard to achieve for a charging depot.

2.3.4 C4 Smart charging of light commercial vehicles

Use case lead	**ELAADNL – Baerte de Brey**
Use case context	One of Elaad's shareholders, Dutch grid operator Stedin, embraced a strategy of fully electrifying their fleet. The fleet is a mix of "normal" passenger vehicles for staff, account managers etc. For their engineers, a fleet of over 800 full electric light duty vehicles is in operation. Together with this roll out of the vehicles, a roll out of smart charging stations was started for the Stedin locations. Apart from installation of a covering network of smart charging station at the headquarters and the depot, charging infrastructure in the vicinity of the homes of the engineers were installed. Given the fact that every country and every city have an electricity grid and grid operators, and many regions in the European Union have the same air quality issues, there might be a business case for light duty vehicles (LDV) with vehicle to load (V2L) for grid maintenance. However, this is not an off-the-shelf solution. It necessitates retrofitting of vehicles, at the moment thus adding additional costs. Also, there is no insight what the impact on the grids or the business cases are if the vehicles are able to do V2G.
Use case description	A pro-active approach was taken, retrofitting a majority of the fleet with additional batteries and inverters to allow Vehicle to Load and thus meet the requirements. The Stedin vehicles are in operation, the chargers are installed in the past years. All are being monitored and are generating data.
Use case goal	Project data will be analysed to give insight what the impact of large scale smart charging by LDV is on the grids, what the business cases are and what opportunities there are if the vehicles are able to do V2G. Elaad has worked together with Stedin and USI to plan this research. 

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

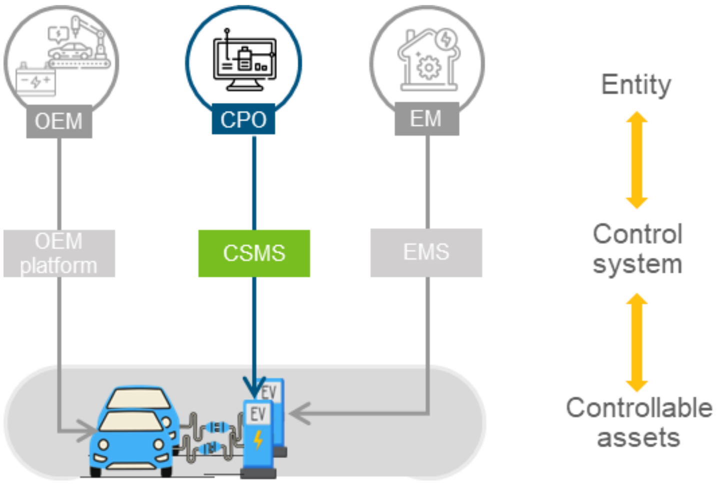
Innovation Clusters				**C: Smart charging of light and heavy-duty fleets**
Use case number				**C4**
Use case				**ELAAD**
Mobility services			Type of service	Company cars
Charging services		AC	Unidirectional	✓
			Bidirectional	✓
		DC	Unidirectional	
			Bidirectional	
			Fast charging	
Energy services	**Local behind-the-meter optimization**	Increase self consumption of on-site renewables	V1G	✓
			V2X	
		Reduce demand charges	V1G	✓
			V2X	
		Time-of-Use shifting	V1G	✓
			V2X	
		Provide back-up power	V1G	✓
			V2X	✓
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	✓
			V2X	✓
		Short term congestion management	V1G	✓
			V2X	✓
		Operational congestion management (near real-time)	V1G	✓
			V2X	✓
		Power Quality control	V1G	✓
			V2X	✓
System architecture		**Control topology**	OEM	
			CPO	
			EM	
		Communication protocols	EV - Charger	IEC 61851 / ISO 15118-20
			Charger -EMS	OCCP 2.0.1
			Charger -CPO	OCCP 2.0.1
			CPO - SCSP	OCPI 2.2
			CPO - eMSP	OCPI 2.2

Evaluation pilot objectives	
Objective	Reduce peak load through smart charging.
Evaluation	As of 2024, the use case is operational with V1G smart charging. V2L is on board and in daily operation.
Objective	Increase renewable energy utilization by smart charging and feed in of PV installation.
Evaluation	The fleet operator is provided with real-time data, improving the business case in optimization of charging. Data shows that when a lot of renewable energy is generated, prices are low.
Objective	Cost savings by preventing grid reinforcements.
Evaluation	The fleet operator is provided with real-time data, improving the business case in optimization of charging. Data shows that when a lot of renewable energy is generated, prices are low.

Evaluation KPIs/ upscaling potential	
Objective	Increased to 300 light commercial vehicles (2025).
Evaluation	The total fleet consist of 2200 vehicles, of them are 800 LDV. All vehicles, including the LDVs are electrified after the normal depreciation scheme. Electrification of the LDV fleet was increased due to local emission regulation. The 40 biggest Dutch cities close their inner cities with an emissions free zone. Many of these cities are in Stedin's territory, and to maintain operational most of the 800 vehicles are electrified.
Objective	Increased share of renewable energy used for charging.
Evaluation	The energy contract of Stedin is 100% renewables.

Evaluation Charging services	
AC	Evaluation is done on meterdata from the chargers and the vehicles by the university of Delft.
DC	DC charging is incidentally done at fast charging stations and is not in scope of this deliverable

Evaluation System architecture	
Control topology	*CPO-CSMS-Chargers-EV*
Evaluation	The topology is operational. V1G operation according tot ISO15118-2&20/OCPP2 is being implemented into chargers.
Communication protocols	*ISO15118-2&20; IEC61851; OCPP2.0.1; OCPI2.2; DA, Equigy, GOPACS, OEM proprietary*

Evaluation	The protocols are in place except for the link to the Equigy/aFRR platform, which is under development by Equigy together with WDS and Enervalis and of which a test is foreseen when V2G cars have arrived early 2025, and the link to the congestion management platform GOPACS, which is developing an interface (in the framework of the ROBUST project) also with a V2G test foreseen spring 2025. 

2.4 Innovation cluster D: Smart public charging

In this innovation cluster, charging is taking place at public locations. Over 50% of the EU population lives in apartments, leaving EVs to be parked in on, or off-street, parking. Smart charging and V2X services can make big impacts through the large amount of available parked EVs. SCALE will implement and test ecosystems of smart charging and V2X that will help municipalities and parking operators to manage energy demand, relieve local congestion, and support in reducing peak loads. Also, the call for a 'right to plug' in apartments and non-residential buildings increase the importance of charging infrastructure capable of reducing the need for grid reinforcements.

2.4.1 D1 EV chargers in Lilleaker Oslo, Smart Charging and V2G for public in commercial and residential neighbourhood

Use case lead	**CURRENT - Åsmund Frengstad**
Use case context	Oslo, Norway. The challenge is operational cost for landlords to supply EV charging to all the tenants, especially grid tariff because of Peaks. In addition, looking into how local produced power could be an asset to reduce the cost.
Use case description	'Mustad Eiendom' is a property owner in Oslo that owns 350 000 m2 and plans to re-develop the whole portfolio located on the pilot premises. At the location there is a shopping mall, a waterfall with power production and abundant office space. Today, they are operating approximately 250 AC charging stations and are looking for ways to reduce cost and increase user charging experience. By applying Smart Charging and V2G, the charging

	plaza should lower the peak max, and the load curve should align (inverted) with local production and energy prices. This use case focuses on demonstrating how these strategies can be implemented in real-world scenarios to deliver mutual benefits for energy stakeholders, charging operators, and EV drivers. The pilot site was change, since the initial planed partner, wanted to derisk their operation and only use proven technology for delivery. This have resulted in some change of KPI and focus on passenger cars save heavy duty.
Use case goal	The primary goal of this use case is to optimize the economic and operational efficiency of electric vehicle (EV) charging infrastructure through innovative energy management strategies and business model development. This use case focuses on demonstrating how these strategies can be implemented in real-world scenarios to deliver mutual benefits for energy stakeholders, charging operators, and EV drivers. The objectives are: • **Reducing Grid Fees with Smart Charging** By implementing intelligent, data-driven charging strategies, the system aims to shift EV charging to periods with lower grid fees. This approach minimizes peak load contributions and utilizes demand-response signals to align charging schedules with grid capacity and pricing, resulting in cost savings for both EV owners and operators. • **Generating Revenue from Flexibility with Smart Charging** Leveraging unidirectional Smart Charging capabilities, the system will participate in flexibility markets by adjusting charging patterns in response to grid needs. This ensures efficient use of energy resources while creating a new revenue stream for charging operators. By enabling a seamless integration with energy markets, the project maximizes value extraction from flexibility services. **Establishing a Viable Business Model for Vehicle-to-Grid (V2G)** The project aims to develop a business model that includes EV drivers as active participants in the V2G ecosystem. By addressing technical, economic, and regulatory challenges, the model seeks to incentivize drivers to provide grid services through their EVs. This will ensure that drivers are fairly compensated for their contributions while enhancing the resilience and stability of the energy grid.

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				D: Smart public charging
Use case number				D1
Use case				Current
Mobility services			Type of service	Private & company cars
Charging services		AC	Unidirectional	
			Bidirectional	
		DC	Unidirectional	✓
			Bidirectional	✓
			Fast charging	
Energy services	Local behind-the-meter optimization	Increase self consumption of on-site renewables	V1G	
			V2X	
		Reduce demand charges	V1G	✓
			V2X	✓
		Time-of-Use shifting	V1G	✓
			V2X	✓
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	✓
		Intraday portfolio optimization	V1G	
			V2X	✓
	System balance	FCR	V1G	✓
			V2X	✓
		aFRR	V1G	✓
			V2X	✓
		mFRR	V1G	✓
			V2X	✓
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	✓
			V2X	✓
		Short term congestion management	V1G	✓
			V2X	✓
		Operational congestion management (near real-time)	V1G	✓
			V2X	✓
		Power Quality control	V1G	✓
			V2X	✓
System architecture		Control topology	OEM	
			CPO	✓
			EM	
		Communication protocols	EV - Charger	ISO 15118-2 / ISO 15118-20
			Charger -EMS	OCPP 1.6-2.1
			Charger -CPO	OCPP 1.6-2.1
			CPO - SCSP	OCPI 2.2
			CPO - eMSP	OCPI 2.2

Evaluation pilot objectives	
Objective	Reduce cost for charging through smart charging (avoiding peak loads) while delivering enough power in time.
Evaluation	Reduction in Grid Costs: Successfully reducing grid operational costs is a significant achievement. This demonstrates the effectiveness of the implemented smart charging strategies in avoiding peak loads, which typically result in higher grid fees. Power Delivery in Time: Ensuring that sufficient power is delivered within required timeframes is critical to maintaining user satisfaction and meeting operational demands. If this goal was met, it highlights a balance between cost efficiency and functionality, validating the viability of the approach. Potential for Scaling: The achievement suggests scalability potential, where similar strategies could be implemented across additional sites to yield comparable cost savings.
Objective	Profitable business case for the owner of the parking places.
Evaluation	**Preliminary Result:** The calculated value of energy flexibility is €5.5 per month per charger. Switching from a fixed-price to a dynamic energy pricing model increases revenue by 10%, with implementation starting on December 1, 2024. **Value of Energy Flexibility:** A monthly flexibility value of €5.5 per charger demonstrates that energy optimization efforts provide tangible monetary benefits. While this amount may seem modest on a per-charger basis, the cumulative value across multiple chargers can create a significant revenue stream, particularly for large parking facilities. Highlighting this value strengthens the case for adopting energy flexibility solutions. **Impact of Pricing Model Change:** Switching from a fixed-price to a dynamic pricing model reflects a strategic decision to align energy costs with market fluctuations. The projected 10% revenue increase indicates a clear financial improvement, enhancing the profitability of the business case for parking lot owners. By implementing this change from December 1, 2024, the project takes a proactive step toward financial sustainability and adaptability to energy market dynamics. **Profitability Assessment:** Combining energy flexibility gains (€5.5 per charger) with increased revenue from dynamic pricing demonstrates a multi-pronged approach to profitability. While these changes improve the financial outlook, further analysis should ensure they account for operational costs, such as hardware investments, software systems, or maintenance related to flexibility solutions. Scalability and Long-Term Impact:

	If the dynamic pricing model and flexibility value prove successful at one location, they could be scaled across other sites to significantly amplify total revenue. Additionally, ongoing participation in energy markets or integration with vehicle-to-grid (V2G) services could further enhance long-term profitability.
Objective	Couple the EV smart charging and building energy management system with open interface to enable dynamic load balancing.
Evaluation	**Preliminary Results:** - Integration has been challenging due to the variety of systems across different buildings. - Positive results have been achieved using local controllers, such as Schneider's Load Management System connected to exostructure, in some main buildings. - Full efficiency requires developing or implementing an EMS capable of integrating both CPO systems/chargers and other building-related assets. **Challenges with System Integration:** - The variety of building systems highlights the complexity of achieving standardization across diverse environments. This underscores the need for adaptable, open-interface solutions. - The struggle to find a common integration approach reflects the fragmented nature of the building and energy technology ecosystem, which is a known industry-wide challenge.
Evaluation continued	**Positive Results with Local Controllers**: - The success with Schneider's Load Management System and Exostructure in main buildings demonstrates the feasibility of dynamic load balancing when leveraging robust, localized solutions. - These initial results provide a strong proof of concept and a foundation for further development. However, the approach's scalability and compatibility with other systems need assessment. **Need for a Unified EMS**: - A comprehensive EMS capable of integrating CPO systems/chargers with other building assets is critical to achieving full efficiency and unlocking the system's potential. - This indicates that the current solution is a step forward but not a complete answer to the objective. The lack of an overarching, integrative system limits the ability to dynamically balance loads across all assets efficiently. ****Scalability and Long-Term Viability:**** - Without a unified EMS, replicating positive outcomes across different buildings or scaling the solution will remain challenging. Developing or adopting an EMS with open standards and interoperability should be a priority. - The open-interface requirement is critical to future-proof the system, ensuring it can adapt to new technologies and standards. **Conclusion:** Progress has been made toward the objective with successful local implementations, but the lack of a unified EMS limits the solution's scalability

	and full efficiency. The next steps should focus on developing or adopting an open-interface EMS capable of integrating all necessary systems, thereby achieving dynamic load balancing and maximizing operational benefits.

Evaluation KPIs/ upscaling potential	
Objective	Increase to 300 charge points in the parking garage.
Evaluation	Currently the facility has increased to 212 Charge Points and in addition 12 High power DC stations which have been added to the location (although, these are outside the project).
Objective	Increase utilization of chargers from 3% to 10%.
Evaluation	Increased utilization from 3% to a new minimum of 9% per month with a peak of 13,876%.
Objective	A positive business case for converting static chargers to smart chargers in parking lots/garages.
Evaluation	**Preliminary Results:** • Findings indicate a positive business case. • A new commercial model will be implemented starting December 1, 2024. **Positive Business Case Validation:** • The indication of a positive business case suggests that converting static chargers to smart chargers offers tangible financial benefits. • Key factors likely contributing to this positive outcome include: o Cost Savings: Reduced energy costs through load management and peak load avoidance. o New Revenue Streams: Participation in energy flexibility markets or dynamic pricing models. o Improved Utilization: Enhanced efficiency in energy distribution and better management of charging demand. **New Commercial Model:** • The decision to implement a new commercial model from December 1, 2024, signifies a strong commitment to transitioning toward smart charging systems. • The success of this model will depend on its ability to address stakeholder needs, such as parking lot owners, EV drivers, and energy providers, while balancing costs and revenue. Market Competitiveness: • Smart chargers can provide a competitive edge for parking lot operators by offering added value to customers (e.g., faster charging, dynamic pricing options, and potential integration with renewable energy). • This competitive advantage reinforces the long-term sustainability of the business case. **Scalability:** • Positive results at pilot or initial locations suggest scalability potential. Expanding the adoption of smart chargers across more parking lots/garages can amplify the financial and operational benefits. • However, considerations such as initial investment costs, system compatibility, and operational training may impact scalability.

	Risk Factors: • While findings are promising, the business case could face risks such as: o Resistance from stakeholders to adopt new systems. o Potential misalignment between expected revenue increases and initial capital costs. o Dependence on regulatory frameworks and energy market dynamics to maintain profitability.

Evaluation Charging services	
AC	Uni directional Smart Charging AC
DC	Bi directional DC

Evaluation Energy Management Services	
1. Primary objective: Optimization of smart charging features in connection with car sharing operation	
Evaluation	**Preliminary Results:** • Progress is currently stalled due to: o Awaiting the car-sharing company's implementation of the Open Charge Point Interface (OCPI). o Awaiting OEM implementation of ISO 15118 to utilize the vehicles' native data sources. **Dependencies and Implementation Delays:** o The objective's reliance on third-party systems and standards (OCPI from the car-sharing company and ISO 15118 from OEMs) has created bottlenecks. o While these technologies are critical for interoperability and advanced data utilization, the waiting period delays the optimization of smart charging features and hinders real-time progress. **Potential Benefits Post-Implementation:** o OCPI Integration: § Facilitates seamless communication between the car-sharing system and the charging network. § Enables features such as dynamic pricing, enhanced booking capabilities, and transparent billing. o ISO 15118 Integration: § Utilizes vehicle-side data for plug-and-charge functionality, state-of-charge (SoC) awareness, and real-time energy needs. § Enhances the efficiency of smart charging algorithms by optimizing charging sessions based on vehicle-specific data. **Impact on Optimization Goals:** o Full optimization depends on real-time, accurate data exchange between the vehicle, car-sharing platform, and charging network. o The lack of these integrations limits the ability to: § Adjust charging based on car-sharing schedules or demand.

	§ Provide cost and energy-efficient solutions aligned with operational needs. o However, the planned implementations of OCPI and ISO 15118 will provide foundational improvements once completed. **Strategic Alignment with Industry Trends:** o The focus on OCPI and ISO 15118 aligns with industry-standardization efforts, ensuring long-term compatibility and scalability. o The integration of these protocols will future-proof the system and make it competitive as car sharing and EV adoption grow. **Conclusion:** While the objective to optimize smart charging in connection with car-sharing operations is delayed, the planned implementation of OCPI and ISO 15118 holds significant promise for achieving this goal. In the interim, proactive measures such as temporary integrations, stakeholder engagement, and algorithm testing can help maintain momentum and readiness. Long-term, these standards will enhance interoperability, data accuracy, and operational efficiency.
2. Secondary objective: Reducing building's electrical power capacity and saving operational costs this way	
Evaluation	**Preliminary Result:** • Operational costs have been reduced by implementing smart charging and linking charging costs to dynamic day-ahead energy pricing. • Grid fees at the location have been lowered through the introduction of virtual peak limitation for charging capacity. **Reduction in Operational Costs:** o Dynamic Pricing: § Linking charging costs to dynamic day-ahead energy pricing allows for cost-effective energy procurement. § This approach leverages lower-priced energy periods, reducing overall operational costs while ensuring charging needs are met. o This demonstrates an effective use of demand-response mechanisms to align energy consumption with market pricing. **Lowering Grid Fees with Virtual Peak Limitation:** o The introduction of a virtual peak limitation on charging capacity successfully reduces peak power demands. o Grid fees are typically determined by maximum demand; limiting peaks directly decreases these costs. o This measure not only improves cost efficiency but also supports grid stability by smoothing demand patterns. Impact on Electrical Power Capacity: o Reducing the building's effective power capacity requirement aligns with the objective, as peak shaving through virtual limitations optimizes energy usage. o This approach avoids unnecessary capacity upgrades, further contributing to cost savings and sustainability.

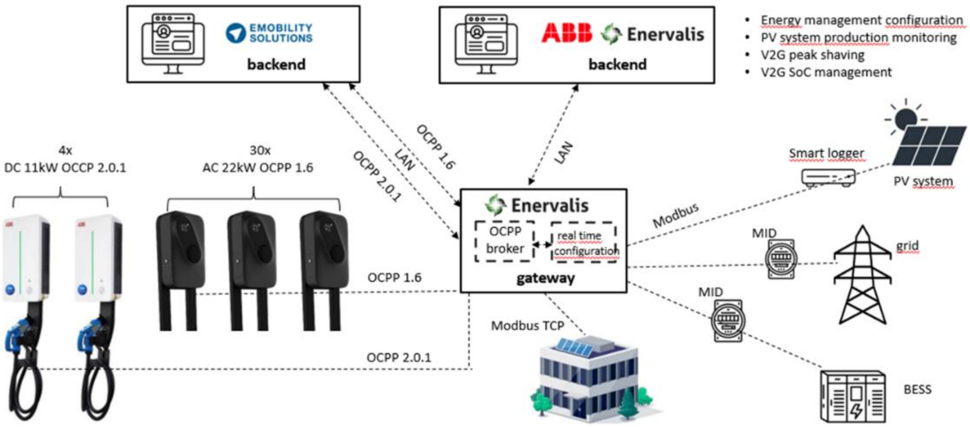
	Effectiveness of Smart Charging: o Smart charging strategies, such as prioritizing energy usage during off-peak times or managing charging schedules dynamically, are central to these successes. o By optimizing charging operations, the building reduces stress on its electrical system while meeting charging demands efficiently. **Scalability and Long-Term Impact:** o These results suggest the measures are scalable and could be applied to other locations or facilities. o The operational model aligns well with future energy trends, such as greater integration with renewable sources and flexibility markets. **Conclusion:** The objective of reducing the building's electrical power capacity and operational costs has been effectively achieved. Smart charging and dynamic pricing strategies have minimized costs, while virtual peak limitations have reduced grid fees. These measures demonstrate financial and operational success and position the system as a scalable, efficient solution for energy management in buildings.

Evaluation System architecture
Control topology & Communication protocols Same challenges and learnings as outlined in use case C1

Evaluation of overall pilot results
The pilot is showing promising progress despite implementation and compliance issues. The findings so far indicate that the overall concept is sound, but technical challenges related to flexibility management, V2G integration, and compliance need to be addressed for the system to function optimally. The next steps should focus on resolving the firmware and system integration issues, testing the flexibility and V2G functionality, and ensuring that these innovations translate into upstream revenue streams and financial sustainability.

2.4.2 D.2 Installation of public chargers with V2G certification

Use case lead	**Emobility Solutions (EMS) - Janos Ungar & Tamás Tóth-Báló**
Use case context	The use case will take place in Erzsebetvaros, one inner city district of Budapest, at a traditional market Hall, that was built in 1897 and renovated in 2015. The V2G capable chargers to be installed could be used by the public in V1G in the project period and by a V2G compliant car (TBD) leased via the project for selected users for testing and demonstration. As part of a newly designed energy community, we will demonstrate how such a system including a PV system, 2 smart V2G AC charging stations and a storage system enables to maximize the level of renewable energy usage and decreases dependence from public electricity network while also making use of the battery capacities of the vehicles parked at the site as buffer and as balancing capacity as well. 
Use case description	At Emobility Solutions use case, at the market hall also positioned as one of Hungary's first energy community system developed and operated by a local government, 2 units of Alfen Twin 5 bidirectional chargers have been installed to demonstrate V2G functionality. The building is equipped with a 100kWp rooftop solar PV and 100 kWh BESS (both installed by EMS) to create a complex energy management system. A V2G compliant EV would be used in the demonstrations in 2024. 
Use case goal	The main goals with this use case are the followings: • One of the main goals is to increase the self-consumption of the onsite solar PV through V1G and V2G technology. Through V1G, this is achieved

	by charging the EV when there is excessive PV production. Using the V2G, this is achieved by saving the extra power of solar PV at sunny time by charging the EV and realising the energy (discharging the EV) when required in the building at peak time. • Reduction of the electricity bills for the building is another important goal to be achieved in this use case. In this scenario, the EV will be charged at off-peak time when the electricity price is low and will be discharged at peak times when the demand for electricity is high. • Due to high power tariffs, reducing the peak load is another goal to be achieved by this use case. In this scenario, the EV scheduling will be done to not charge the EV at peak time, and if possible to discharge it during that period. • The demonstrations will be conducted following a modification of the ISO standard 15118-2 and later utilizing a full integration of the 15118-20 standard for the V2G communication. As a conclusion this use case will demonstrate the following scenarios: • Solar charging • Load management • V2G peak shaving 

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				**D: Smart public charging**
Use case number				**D2**
Use case				**Emobility Solutions**
Mobility services			Type of service	Private & company cars
Charging services		AC	Unidirectional	
			Bidirectional	✓
		DC	Unidirectional	
			Bidirectional	
			Fast charging	
Energy services	**Local behind-the-meter optimization**	Increase self consumption of on-site renewables	V1G	
			V2X	✓
		Reduce demand charges	V1G	✓
			V2X	✓
		Time-of-Use shifting	V1G	
			V2X	
		Provide back-up power	V1G	
			V2X	✓
	Balance responsibility	Wholesale market price arbitrage	V1G	
			V2X	
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	
			V2X	
		Short term congestion management	V1G	
			V2X	
		Operational congestion management (near real-time)	V1G	
			V2X	
		Power Quality control	V1G	
			V2X	
System architecture		**Control topology**	OEM	
			CPO	
			EM	✓
		Communication protocols	EV - Charger	ISO 15118-2 / ISO 15118-20
			Charger -EMS	OCCP 2.0.1
			Charger -CPO	OCPP 1.6, OCPP 2.0.1
			CPO - SCSP	n.a.
			CPO - eMSP	n.a.

Evaluation pilot objectives	
Objective	Reduce grid dependency by creating a green micro grid, aggregating the PV generation and energy consumption.
Evaluation	The installaton of the PV system and BESS has been completed and is operational. In the next phase we collect the relevant usage data to see how this system can be used to optimize the energy consumption of the use case site.
Objective	Execute multi-location demand-side & load-management.
Evaluation	Together with Enervalis we can handle different scenarios, such as solar charging. We are also able to control the energy flow towards the BESS or towards the higher demand areas of the use case such as the market hall grocery store.
Objective	Increase ‘plug-in’ rate through a loyalty program, motivating customers to utilize smart and preferred charging behaviour.
Evaluation	Together with the local municipality our system is ready to introduce loyalty program. The only thing missing is the supportive legislation environment, which depends on the Hungarian Government.

Evaluation KPIs/ upscaling potential	
Objective	Utilization of this model is expected to be implemented all over the Municipality’s territory.
Evaluation	
Objective	Proof scalability by simulating the District-wide charging network
Evaluation	
Objective	14 V2G certified EVSE installed
Evaluation	
Objective	Policy recommendation for the local municipality
Evaluation	
Objective	Based on result of Task 2.6 1 time offline training for the Municipality
Evaluation	

Evaluation Charging services	
AC	Bidirectional charging using AC charger based on OCPP 22.0.1 will be demonstrated. The EMS communicate with the charger through Terra Gateway Pro.

Evaluation Energy Management Services	
The energy management system (EMS) will be developed by EMS and Enervalis in which different goals will be followed.	
1. Primary objective: To develop an optimal EMS to reduce the electricity cost of the use case by V2G. This also includes peak load reduction of the use case.	
Evaluation	The demonstrations are ongoing and the results will be evaluated in terms of cost reduction for the different charge scenarios
2. Secondary objective: To develop an optimal EMS to increase the self-consumption of solar PV and hence reduce the carbon emission to get as close as possible to a net zero emission in this use case.	
Evaluation	The demonstrations are ongoing and the results will be evaluated in terms of carbon emission reduction for the different charge scenarios

Evaluation System architecture	
Control topology	*EM, CPO*
Evaluation	
Communication protocols	*OCPP, OCPI*
Evaluation	

Evaluation of overall pilot results
Communication (interoperability) between systems within the pilot site is key. Not only hardware elements, but V2G capable vehicles are also needed to successful tests. Without supportive legislation environment V2G cannot spread widely.

2.5 Innovation cluster: overarching use case

Because the Utrecht use case overarches several innovation clusters and does not specifically fit to one single cluster, it is described separately in the following section. Applicable charging scenarios are: congestion management, grid balancing (via AFRR), demand charge reduction, time-of-use price arbitrage, maximized feed-in of renewables and virtual power plant.

2.5.1 Use case 00: Bi-directional ecosystem via combined V2G service

Use case lead	**We Drive Solar (WDS) - Bart van der Ree, Robin Berg**
Use case context	In Utrecht, the Netherlands, a world-wide unique bi-directional ecosystem is created which currently is the largest V2G living lab in the world. It consists of (at the time of writing) about 700 AC-bidirectional charging stations and almost 400 smart-charging shared EV's. The 'Utrecht bidirectional Ecosystem'  supports power system stability, supplies flexibility to the electricity grid with the goal to reduce / postpone grid reinforcement costs and lowers the peak load of the power system, and it is a major driver for innovation and upscaling of AC-V2G technology. This use case has been set up to prove the potential benefits – electricity grid robustness, urban environment benefits, when AC-V2G services are scaled up – which is the plan of City of Utrecht, We Drive Solar and EV sharing partner MyWheels, and a for the coming years.

Use case description	Unique is that the pilot is based on a fleet of V2G cars which is owned by a single professional entity, this enables easy bundling, intelligent charging management and fast upscaling of innovations. Part of the 700 V2G chargers is operated to charge these shared cars, which are 'station based', which means that they are always connected to their V2G charger and available for smart and V2G charging whenever not booked. Most of the other V2G chargers are active as 'normal' on-street public charging also for non-V2X ready cars.
Use case goal	The primary objective of the Use Case is to enable fast further expansion of electric mobility and sustainable energy production without the associated excessive grid loads and high costs for grid reinforcement. When scaled up, smart and bidirectional charging are expected to have a large positive impact on grid balance and congestion. Secondary, but more immediate objective is to improve the business cases for EV charging and EV car sharing and thus to promote EV upscaling. The main goals of the use case are: • Congestion management – reducing and/or delaying the need for future grid reinforcements with associated high societal costs, thus also reducing the future costs of EV driving for all users. • Grid balancing (via Day Ahead / FCR / AFRR) and Time-of-use price arbitrage - reducing charging costs for shared EV exploitation and private EV charging • Maximized utilization of renewables by EV's • Creating a virtual power plant. that can deliver above services in order to reduce grid reinforcement costs as well as EV charging / driving costs in the future.

Use case scope

The below table presents an overview of the scope of the use case based on the evaluation framework as provided in chapter 1. For the complete overview of the use case setup see D3.1. Use case setup report.

Innovation Clusters				Hybrid
Use case number				00
Use case				We Drive Solar
Mobility services			Type of service	Car-sharing; private cars
Charging services		AC	Unidirectional	✓
			Bidirectional	✓
		DC	Unidirectional	
			Bidirectional	
			Fast charging	
Energy services	Local behind-the-meter optimization	Increase self consumption of on-site renewables	V1G	✓
			V2X	✓
		Reduce demand charges	V1G	✓
			V2X	✓
		Time-of-Use shifting	V1G	✓
			V2X	✓
		Provide back-up power	V1G	
			V2X	
	Balance responsibility	Wholesale market price arbitrage	V1G	✓
			V2X	✓
		Intraday portfolio optimization	V1G	
			V2X	
	System balance	FCR	V1G	
			V2X	
		aFRR	V1G	
			V2X	✓
		mFRR	V1G	
			V2X	
		Strategic reserves (adequacy)	V1G	
			V2X	
	Congestion management	Long-term Flexibility agreement	V1G	✓
			V2X	✓
		Short term congestion management	V1G	✓
			V2X	✓
		Operational congestion management (near real-time)	V1G	✓
			V2X	✓
		Power Quality control	V1G	✓
			V2X	✓
System architecture		Control topology	OEM	
			CPO	✓
			EM	
		Communication protocols	EV - Charger	IEC 61851 / ISO 15118-20
			Charger -EMS	OCCP 2.0.1
			Charger -CPO	OCCP 2.0.1
			CPO - SCSP	OCPI 2.2
			CPO - eMSP	OCPI 2.2

Evaluation pilot objectives	
Objective	Construct an operational Virtual Power Plant.
Evaluation	Per October 2024, the UC is operational with mass V1G smart charging and reacting to ToU tariffs as well as congestion management signals. V2G operation is being tested and from February 2025, the introduction of about 50 V2G shared EVs into the system is expected and the full Virtual Power Plant will become operational.
Objective	Execute mix of congestion management, Time of Use price arbitrage, demand charge reduction, and increase flexibility on the grid via FCR/AFRR.
Evaluation	ToU price arbitrage and demand charger reduction are operational on about 700 WDS chargers in Utrecht. Congestion management is operational (and still being tested and optimised) with a group of about 400 WDS chargers. Lastly, aFRR access is being tested in cooperation with Equigy.
Objective	Find the potential flexibility capacity that V2G car sharing programs can deliver to the grid and what individually distributed low power chargers can offer in flexibility.
Evaluation	The potential flexibility capacity of V2G car sharing programs has been evaluated by UU and TU Delft; considerable impact has been found. Once a fleet of V2G shared EVs is operational in spring 2025, these calculations will be validated.
Objective	Prevent customer lock-in and competition lock-out by using open standards and protocols.
Evaluation	The chargers of WDS have always used the open standard ISO15118 and open communication protocols. An upgrade to full compliance with the newer open ISO15118-20 standard is starting rollout and will be operational in about 2000 chargers in 2025.

Evaluation KPIs/ upscaling potential	
Target	Reduce costs for grid reinforcement by 88% compared to situation without smart charging.
Evaluation	Utrecht University and Delft Technological University have evaluated that with V2G, the grid load from the chargers can become negative during peak (evening) hours. This implies that with full V2G operation, there are no costs for grid reinforcement for the chargers, on the contrary, the grid load will decrease in evening hours and room is created on the existing grid for other electricity consumers such as households. This could be achieved through congestion management measures such as GOPACS or capacity-limiting contracts.
Objective	Aggregate 25 MWh in battery storage by implementing 500 V2G capable shared E-cars and 3000 V2G capable public charging points.
Evaluation	WDS expects to have 500 V2G capable shared E-cars in operation (with their car sharing partner MyWheels) within the year 2025. The combined battery capacity of these e-cars will be around 25 MWh. By end 2025, WDS plans to have 2000 V2G chargers operational (in Utrecht and in other Dutch cities); that number is expected to further double within a few years. Other CPOs in Utrecht presently have about 2000 V2G-prepared public chargers operational.
Objective	Peak load reduction by 10 MW through aggregated flexibility of the 500 V2G cars.

Evaluation	Compared to situation without smart charging, the 500 V2G cars would not only reduce the charging in peak hours (about 20kW per car) to zero, which would reduce the load by up to 10MW, but would even deliver energy (up to 11kW per EV or an additional 5MW) during the peak hours. Thus, the 10MW reduction is well within operational range.
Objective	Cars used by 4.000 households & chargers used by 30.000 different EV owners.
Evaluation	The 500 V2G EV in operation by end 2025 will cater for around 4.000 households. The total fleet of WDS chargers is expected to grow to thousands in 2026-2027, with tens of thousands of EV owners charging at the public chargers.
Objective	Potential reduction in charging time of 83%, compared to conventional 3kW public chargers.
Evaluation	The charging power of the WDS chargers is on average about 17kW, which reduces the charging time by 83% compared to 3kW charging. This creates additional time before the cars are needed again, to optimize smart and V2G charging.

Evaluation Charging services	
AC	Public AC V2G and V1G charging and of shared EV's.

Evaluation Energy Management Services	
1. Primary objective To enable fast further expansion of electric mobility and sustainable energy production without the associated excessive grid loads and high costs for grid reinforcement.	
Evaluation	The arrival of ISO15118-20 compatible V2G cars on the market has seen a delay, their arrival is foreseen early 2025 and upscaling and fast further expansion is foreseen in 2025 and the years after. The shared EV scheme driven by WDS partner MyWheels will adopt large numbers of V2G EV in a fast pace (50 per month foreseen up to 500 V2G vehicles by end of 2025) as part of their lease fleet expansion and renewal. The implementation of V2G for congestion management is then foreseen to avoid much of the associated grid loads and grid reinforcement costs as compared to non-smart charging.
2. Secondary objective Secondary, but more immediate, objective, is to improve the business cases for EV charging and EV car sharing and thus to promote EV upscaling.	
Evaluation	At the time of writing, October 2024, the Business Case is being evaluated, both for V1G and V2G operation of shared E-cars in cities. Combined benefits from Time of Use price arbitrage, demand charge reduction, and (from 2025) AFRR balancing market and GOPACS congestion management platform, will lead to strong improvement of the business case for EV charging and also for EV car sharing (which at this time is still hard to make profitable, considering the number of EV car sharing companies that withdrew from the market). Further extension of the number of V2G car models on the market, fit for open protocol public charging as well as for home V2X charging, will allow for rapid further upscaling.

Evaluation System architecture	
Control topology	*CPO-CSMS-Chargers-EV*
Evaluation	The topology is operational. V2G operation according tot ISO15118-20/OCPP2 is being implemented (October 2024) into chargers and compatible EV are expected on the market Q1 of 2025.
Communication protocols	*ISO15118-20; IEC61851; OCPP2.0.1; OCPI2.2; DA, Equigy, GOPACS, OEM proprietary*
Evaluation	The protocols are in place except for the link to the Equigy/aFRR platform, which is under development by Equigy together with WDS and Enervalis and of which a test is foreseen when V2G cars have arrived early 2025, and the link to the congestion management platform GOPACS, which is developing an interface (in the framework of the ROBUST project) also with a V2G test foreseen spring 2025.

Evaluation of overall pilot results
The Utrecht Bidirectional Ecosystem - Use Case 00 - is operational on large scale (about 700 V2G chargers and 400 shared EV's) and having a large impact on the local electricity grid. Full V2G operation on large scale is expected to be demonstrated in spring 2025, shortly after the arrival of 50 V2G shared e-cars each month starting February 2025. Links to open electricity grid platforms (Equigy and GOPACS) will also be tested in spring 2025 using V2G operations. The Utrecht partners expect vast upscaling of the Use Case in the Netherlands, towards 500 V2G shared EVs and 2,000 V2G charging points within 2025.

3 Conclusions from use case evaluations

3.1 Introduction

In Chapter 1, the introduction, evaluation framework, deployment steps and use case evaluation sections were presented and described. In Chapter 2, the individual use cases evaluations were presented with specific conclusions from each use case leader. Through the individual use case results displayed in chapter 2, a strong diversity of services being tested can be seen. In this final chapter, use case overarching conclusions on piloting with smart charging and V2X that have been the result of the workshop in Budapest and follow up sessions on this topic are presented.

To display a full overview of the use cases realised scope, five annex tables have been made available in support of the overarching evaluations and summarised findings. These annexes are divided into the below topics following the evaluation framework.

- All services and system architecture combined
- Mobility services
- Charging services
- Energy services
- System architecture

3.2 Common use case evaluation findings

Whereas the findings are derived from individual use case results, a parallel assessment has been performed together with the work package 3 team to come to more generic findings applicable throughout the use cases. For this purpose a qualitative approach has been applied.

As a first step in that process, the commonly discussed topics within the work package 3 team meetings are taken as a point of departure. This has been used to feed a physical workshops with all SCALE partners in Budapest. These results where again presented and discussed in follow up sessions with a smaller team of participants engaged in the use cases. The results of this have been organised in the following eight most relevant topics.

3.2.1 Smart charging and V2X unlocks flexibility

Within the use cases of work package 3 significant progress has been made in the development, testing, and simulation of various smart charging (V1G) and V2X solutions. The use cases have demonstrated considerable potential in unlocking flexibility in energy systems. In particular, the use cases for both smart charging and V2G have shown promising results in contributing to grid balancing across a broad range of energy services. The use of data sources for e.g. planning the mobility requirements, PV production forecast and many other sources can greatly contribute to the flexibility potential of BEVs. Another contributing factor is the integration of additional assets in the flexibility mix, such as Battery Energy Storage Systems (BESS). A full overview of all the energy services tested can be consulted in annex 4.

The adoption of ISO 15118-2 / 20 and OCPP 2.x standards can further enhance the capabilities of smart charging solutions, providing the foundation for more advanced systems that can unlock even greater flexibility. Besides smarter charging solutions, V2X capabilities of EV and charging infrastructure can further increase the potential to offer additional flexibility and contribute even more effectively to grid stability and optimization.

3.2.2 Differences between AC & DC charging

Central to SCALE's objective is to draw conclusions on how different hardware components, with a big emphasis on charge points, can optimally contribute to the smart charging and V2X potential of the different services identified. As seen in the SCALE use cases there are differences in the implementation of smart charging and V2X solutions across use cases. Moreover, a prerequisite for various forms of smart and bidirectional charging is the rolling out of ISO 15118. However, both vehicle and charge point manufacturers are faced with challenges rolling out the protocol. To some extent also for this reason, the availability of V2X capable chargers and vehicles has proven to be a bottleneck experience in several use cases.

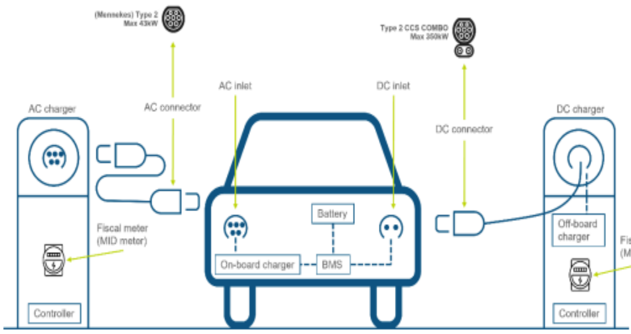


Figure 6. Differences between AC & DC charging

At present, DC charging faces fewer barriers to the implementation of these solutions. One of the key advantages of DC charging is that ISO 15118-2 is already well-established and mainstream, enabling easier integration of advanced functionalities. Additionally, and in relation to bidirectional charging, since the generator is located within the charging point and is not mobile, the *grid* code issue - typically associated with AC charging – is less of a challenge in the case of DC charging systems.

On the other hand, AC charging is seen to have a higher potential to provide flexibility on the long run, despite its current limitations. The installed base of charging infrastructure within the EU is predominantly AC and most vehicles are equipped with onboard chargers, making it a widely accessible and an established technology. Furthermore, the inherent characteristics of AC charging offer greater opportunities for providing grid flexibility, particularly in terms of managing energy flow and optimizing usage based on system needs.

While DC charging is currently more suited to smart - and bidirectional charging and advanced smart functionalities, AC charging holds significant promise for future scalability and flexibility, especially as the technology continues to evolve. What's more, all findings from both technical and operational perspectives indicate that both charging methods can coexist and fulfil complementary roles.

Knowing the present day differences between AC and DC charging, it is important to note that they should not be seen as competing technologies for smart charging and V2X solutions. Both technologies can coexist for charging different vehicle types in different power ranges and in different use cases.

3.2.3 Harmonisation of ecosystem

As concluded earlier, it is demonstrated that ISO15118-2 & 20 and also the OCPP2.x can unlock more flexibility. Looking at the SCALE use cases, the implementation of ISO15118-20 and OCPP2.x in both EV and CP are still in an early stage. Although important steps are being made, to which SCALE contributed, we cannot speak of a truly interoperable ecosystem with these standards. Existing implementations on ISO15118-20 are in pilot phase or have a closed setup where there is only a single combination between EV, CP and EMS or CPMS. An example of the latter is the innovative bidirectional Renault-5 vehicle that is currently commercially offered together with the Mobilize solution for Vehicle-to-Home.

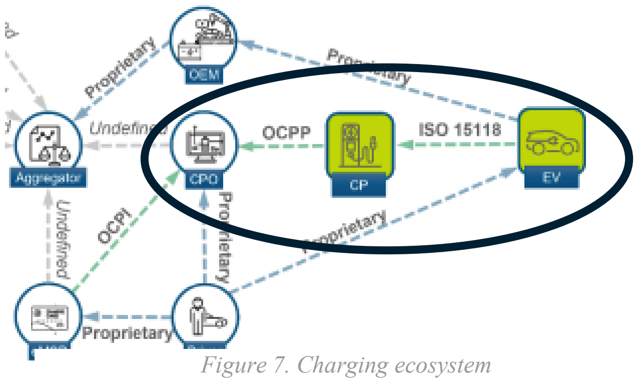


Figure 7. Charging ecosystem

At this stage, it is premature to consider the core of the charging ecosystem (EV, CP and CPMS) fully interoperable with these standards. For broader adoption and seamless integration, additional implementations across the ecosystem are necessary. Furthermore, extensive interoperability testing is required to ensure that diverse components can effectively communicate and function together.

While the interoperability between EV, CP and CPMS is essential and at the core of smart charging solutions, harmonisation must extend beyond these communication standards to also include the energy domain, such as electricity meters, BESS, EMS, DSO, and TSO.

In the use cases, facing the same challenges, the need for a dedicated "system integrator" to navigate the complexity involved in integrating subsystems and performing energy management optimisations appeared important. This proved a great help to ensure the successful deployment of the various smart solutions.

Further harmonisation of these standards in the ecosystem would reduce the dependency on system integrators and enable the faster scaling up and roll-out of smart charging and V2X solutions. Achieving this harmonisation is essential to fully harnessing the flexibility potential of EVs and optimise their contribution to grid stability and energy management.

3.2.4 Access to data

Much related to the previous two paragraphs, access to data has the potential to enable smarter charging and therefore increase flexibility. As concluded also in the SCALE report *Specifications and IT Use-Case definition for V2X services (D2.2)* (Sautreau, J & Meersmans, J, 2023) there is a clear need for data from various sources within both the mobility and energy domain. Moreover, there is a great variety in data requirements in relation to the targeted charge optimisation to execute one or more energy services. See figure 8 for an overview of some key data streams.

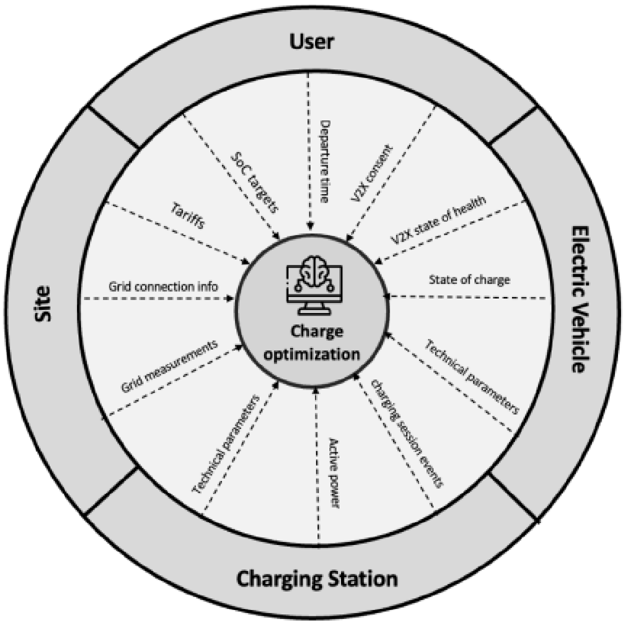


Figure 8. Data requirements for charge optimization

A clear distinction can be made here between 'in front' and 'behind' the meter energy services. Data quality also proved to be an important aspect as the provision of certain energy services required faster and more frequent and/or more accurate data to operate optimally. Of particular relevance, load request predictability plays a key role. Data on the mobility requirement targets such as the SoC at the planned departure time can be used to optimise the charging profiles of the vehicles. This increases the potential role of electric vehicles in grid balancing and behind the meter optimization and can enhance the business case.

In practice however, a general concern in getting access to data comes from the GDPR regulation which requires authorisation to access data or anonymised data. Additionally, getting access to data often means cooperation with one or more stakeholders which often have limited incentive to do so. With the SCALE partners having a clear objective to cooperate and exchange data, this topic is expected to be a more dominant boundary outside of the project and in a 'real-world' environment.

3.2.5 All stakeholders are essential

As experienced by many of the use case leaders whilst implementing their use cases, there is a clear need for participation of all stakeholders in the ecosystem, and this includes relevant ones beyond the SCALE consortium. Often, if one of the key stakeholders is not effectively participating, certain smart charging solutions cannot be implemented. Although this topic already comes up in the *Access to data* topic, see § 3.2.5 of the previous section, it goes beyond data exchange alone.

There are diverse levels of importance between stakeholder involvement to implement and further scale up smart charging and V2X solutions. Key stakeholders in the ecosystem are the EV and CP manufacturers as well as the grid operators. Activation of these stakeholders is key to further scaling up. Besides activation of these stakeholders, challenges faced by manufacturers such as grid code compliance for V2X, and the need for better harmonisation and interoperability should also be accounted for in the run up to mass deployment.

3.2.6 Access to market mechanisms

More advanced market mechanisms also play a crucial role in optimizing the economic potential of smart charging and V2X technologies. As seen in the use cases, access to energy market mechanisms is essential for the profitability of smart charging and V2X solutions; the ability to participate in these mechanisms enables EVs to contribute effectively to balance the grid and capture value from various energy services. The simplest market mechanism, is the feed-in incentive for V2G, which can provide financial benefits for vehicles that return energy to the grid. Other more advanced examples can be divided into 4 categories;

1. **Local behind-the-meter optimization** involving strategies such as considering capacity tariffs and dynamic pricing to reduce energy costs and improve system efficiency.
2. **Balance responsibility** in spot markets, where EVs can participate in real-time energy balancing.
3. **System balancing**, with services like FCR and aFFR to help stabilize grid operations.
4. **Congestion management** solutions, such as GOPACS in the Netherlands, that support grid operators in managing energy distribution and prevent bottlenecks.

Importantly, market mechanisms should address the specific needs of grid operators or BRPs, which can vary significantly from country to country. Additionally, these mechanisms must be adaptable, and adapted, to local regulations and requirements. Furthermore, the role of aggregators holds great potential in unlocking access to balancing and congestion management markets for EVs, with doing so increasing the potential for profitability of the smart charging and V2X solutions.

3.2.7 Consumer awareness

The end consumer plays an integral role in the adoption of smart charging and V2X solutions. A clear demand for these technologies is important for its uptake. That said, consumers need to understand the benefits of the technology whilst also clearly understanding the added value of, for example, V2H use case which would enrich the conversation. In addition, the biggest concern consumers have when looking at all the countries' combined survey results is battery degradation (Aarvold Rastad, Sommerset Busengdal, & Hiep, 2023) as concluded in the SCALE report on consumer behaviour v2 (D1.1). Many recent publications on this topic suggest that the impact of bidirectional charging on battery degradation, when managed carefully, is limited. More effort is needed to increase consumer's awareness on the impact of bidirectional charging in relation to battery life.

3.2.8 Regulatory framework

The current regulatory framework presents several challenges hindering mass deployment of smart charging and V2X technologies. One of the primary obstacles is the existing regulation on grid codes which is limiting the widespread integration of bidirectional charging systems into the energy grid. To unlock the full potential of these technologies, regulatory updates and harmonization are needed to address these barriers.

Additionally, the issue of double taxation is a significant concern in some countries that must be resolved to enhance the business case for V2G solutions. Without clear regulatory guidelines on tax treatment, operators and consumers may face limited financial incentives that eventually impact the profitability and scalability of these systems.

Moreover, feed-in tariffs are also essential to promote the adoption of V2G as they provide an important financial incentive for consumers to participate in energy markets by returning energy to the grid. As with the double taxation issues, it is also important to note that with respect to feed-in tariffs there are different national policies across the EU member states on how to deal with these in the context of bidirectional charging of EVs.

Lastly, there is a need for regulatory frameworks that open up more markets and reduce barriers to access for flexibility services. By making it easier for electric vehicles to participate in flexibility markets and by offering services such as balancing and congestion management, regulators can foster greater integration of smart charging and V2G technologies, hereby contributing to more flexible, efficient, and sustainable energy systems.

3.3 Closing remarks

The two primary objectives of the use case evaluation report were, firstly, to allow use case leaders to assess each use case according to a uniform methodology and, secondly, to compile the overarching findings to accelerate the uptake of smart charging and V2G ecosystems. In chapter 2 all use case leaders reflected on, and evaluated the activities of the project with respect to their own field of work, whereas chapter 3 was composed collaboratively and summarises the findings of the wider group.

In line with the wide scope of testing, this report engages a broad variety of topics and draws parallels between use cases where possible. And yet, the report remains focused on the core tasks relating to each use case. In future SCALE reports, the many facets of the use cases will be explored in different lights and with deeper emphasis on other aspects.

Going beyond the use cases, the SCALE *Lessons learnt reports (D3.4)* will have a greater focus on findings across the broader project and have a greater focus on innovation clusters within the evaluation framework.

For a deeper dive on business aspects of each use case, the SCALE *Business case reports (D3.3)* and *ROI calculation (D5.1)* will, respectively, contain qualitative and quantitative analyses of each use case.

Centred on assessment and monitoring framework activities, upcoming reports from work package 4 will, amongst other, continue the SCALE work on training materials and shed light on impact assessment results of each use case in the following deliverables: *Training material and assessment (D4.5) & Report on Energy, Social and Environmental Impact assessment Results and Platform development (D4.3).*

Finally, in addressing the systems models, protocols and legal & policy recommendations, the following upcoming SCALE reports are also recommended: *System model (D5.2), Legal & policy recommendations (D5.3) and Standards and protocols gap analysis (D.5.5).*

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6 Annex

Annex 1. Use case matrix realised industry value services chain testing and system architecture

Innovation Cluster			Hybrid	B: Smart charging at businesses/ offices				C: Smart charging of light and heavy-duty fleets				D: Smart public charging	
Use case number			00	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2
Use case leader			We Drive Solar	DBH	Emobility Solutions	Enedis	Chalmers	Current	VDL	VDL	ELAAD	Current	Emobility Solutions
Mobility services		Type of service	Car-sharing; private cars	Car-sharing	Private & company cars	Company cars	Company car	Private & company cars	B2B	B2B	Company cars	Private & company cars	Private & company cars
Charging services	AC	Unidirectional	✓	✓	✓	✓	✓	✓			✓		
		Bidirectional	✓								✓		✓
	DC	Unidirectional			✓			✓	✓	✓		✓	
		Bidirectional			✓		✓	✓		✓		✓	
		Fast charging							✓	✓			
Energy services – Local behind-the-meter optimization	Increase self consumption of on-site renewables	V1G	✓	✓	✓	✓	✓				✓		
		V2X	✓		✓		✓						✓
	Reduce demand charges	V1G	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		V2X	✓		✓		✓	✓		✓		✓	✓
	Time-of-Use shifting	V1G	✓	✓	✓			✓		✓	✓	✓	
		V2X	✓					✓		✓		✓	
	Provide back-up power	V1G									✓		
		V2X									✓		✓
Energy services – Balance responsibility	Wholesale market price arbitrage	V1G	✓				✓	✓		✓			
		V2X	✓				✓	✓		✓		✓	
	Intraday portfolio optimization	V1G						✓					
		V2X						✓				✓	
Energy services – System balance	FCR	V1G						✓				✓	
		V2X						✓				✓	
	aFRR	V1G						✓				✓	
		V2X	✓					✓				✓	
	mFRR	V1G						✓				✓	
		V2X						✓				✓	
	Strategic reserves (adequacy)	V1G											
		V2X											
Energy services – Congestion management	Long-term Flexibility agreement	V1G	✓					✓			✓	✓	
		V2X	✓					✓			✓	✓	
	Short term congestion management (D1)	V1G	✓					✓			✓	✓	
		V2X	✓					✓			✓	✓	
	Operational congestion management (near real-time)	V1G	✓					✓			✓	✓	
		V2X	✓				✓	✓			✓	✓	
	Power Quality control	V1G	✓					✓			✓	✓	
		V2X	✓					✓			✓	✓	
System architecture	Control topology	OEM											
		CPO	✓		✓			✓				✓	
		EM		✓	✓	✓	✓		✓	✓			✓
	Communication protocols	EV - Charger	IEC 61851 / ISO 15118-20	ISO 15118-20	ISO 15118-2 / ISO 15118-20	n.a.	ISO 15118-2 / ISO 15118-20	ISO 15118-2 / ISO 15118-20	n.a.	n.a.	IEC 61851 / ISO 15118-20	ISO 15118-2 / ISO 15118-20	ISO 15118-2 / ISO 15118-20
		Charger - EMS	OCCP 2.0.1	OCPP 1.6	OCPP 1.6, OCPP 2.0.1	OCPP 1.6 (simulated)	OCPP 1.6	OCPP 1.6-2.1	n.a.	n.a.	OCCP 2.0.1	OCPP 1.6-2.1	OCCP 2.0.1
		Charger - CPO	OCCP 2.0.1	OCPP 1.6	OCPP 1.6, OCPP 2.0.1	n.a.	n.a.	OCPP 1.6-2.1	n.a.	n.a.	OCCP 2.0.1	OCPP 1.6-2.1	OCPP 1.6, OCPP 2.0.1
		CPO - SCSP	OCPI 2.2	n.a.	***t.b d.***	n.a.	n.a.	OCPI 2.2	n.a.	n.a.	OCPI 2.2	OCPI 2.2	n.a.
		CPO - eMSP	OCPI 2.2	n.a.	n.a.	n.a.	n.a.	OCPI 2.2	n.a.	n.a.	OCPI 2.2	OCPI 2.2	n.a.

Annex 1. Use case matrix realised industry value services chain testing and system architecture

Annex 2. mobility services per use case

Innovation Cluster	Hybrid	B: Smart charging at businesses/ offices				C: Smart charging of light and heavy-duty fleets				D: Smart public charging	
Use case number	00	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2
Use case leader	We Drive Solar	DBH	Emobility Solutions	Enedis	Chalmers	Current	VDL	VDL	ELAAD	Current	Emobility Solutions
Mobility services	Car-sharing; private cars	Car-sharing	Private & company cars	Company cars	Company car	Private & company cars	B2B	B2B	Company cars	Private & company cars	Private & company cars

Annex 2. Mobility services per use case

Annex 3. Charging services per use case

Innovation Clusters	Use Case	3.5. Charging services				
		AC		DC		
		Unidirectional	Bidirectional	Unidirectional	Bidirectional	Fast charging
Hybrid	00 – We Drive Solar	✓	✓			
A: Smart home charging	A1 – Sono Motors		✓			
	A2 – Sono Motors		✓			
B: Smart charging at businesses/ offices	B1 – DBH	✓				
	B2 – Emobility Solutions	✓		✓	✓	
	B3 – Enedis	✓				
	B4 – Chalmers	✓			✓	
C: Smart charging of light and heavy-duty fleets	C1 – Current	✓		✓	✓	
	C2 – VDL			✓		✓
	C3 – VDL			✓	✓	✓
	C4 - ELAAD	✓	✓			
D: Smart public charging	D1 – Current			✓	✓	
	D2 – Emobility Solutions		✓			

Annex 3. Charging services per use case

Annex 4. Energy services per use case

Innovation Cluster				Hybrid	B: Smart charging at businesses/ offices				C: Smart charging of light and heavy-duty fleets				D: Smart public charging	
Use case number				00	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2
Use case leader				We Drive Solar	DBH	Emobility Solutions	Enedis	Chalmers	Current	VDL	VDL	ELAAD	Current	Emobility Solutions
Energy services	Local behind-the-meter optimization	Increase self consumption of on-site renewables	V1G	✓	✓	✓	✓	✓				✓		
			V2X	✓		✓		✓						✓
		Reduce demand charges	V1G	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			V2X	✓		✓		✓	✓		✓		✓	✓
		Time-of-Use shifting	V1G	✓	✓	✓			✓		✓	✓	✓	
			V2X	✓					✓		✓		✓	
		Provide back-up power	V1G									✓		
			V2X									✓		✓
	Balance responsibility	Wholesale market price arbitrage	V1G	✓				✓	✓		✓			
			V2X	✓				✓	✓		✓		✓	
		Intraday portfolio optimization	V1G						✓					
			V2X						✓				✓	
	System balance	FCR	V1G						✓				✓	
			V2X						✓				✓	
		aFRR	V1G						✓				✓	
			V2X	✓					✓				✓	
		mFRR	V1G						✓				✓	
			V2X						✓				✓	
		Strategic reserves (adequacy)	V1G											
			V2X											
	Congestion management	Long-term Flexibility agreement	V1G	✓					✓			✓	✓	
			V2X	✓					✓			✓	✓	
		Short term congestion management (D1)	V1G	✓					✓			✓	✓	
			V2X	✓					✓			✓	✓	
		Operational congestion management (near real-time)	V1G	✓					✓			✓	✓	
			V2X	✓				✓	✓			✓	✓	
		Power Quality control	V1G	✓					✓			✓	✓	
			V2X	✓					✓			✓	✓	

Annex 4. Energy services per use case

Annex 5. System architecture per use case

Innovation Cluster			Hybrid	B: Smart charging at businesses/ offices				C: Smart charging of light and heavy-duty fleets				D: Smart public charging	
Use case number			00	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2
Use case leader			We Drive Solar	DBH	Emobility Solutions	Enedis	Chalmers	Current	VDL	VDL	ELAAD	Current	Emobility Solutions
System architecture	Control topology	OEM											
		CPO	✓		✓			✓				✓	
		EM		✓	✓	✓	✓		✓	✓			✓
	Communication protocols	EV - Charger	IEC 61851 / ISO 15118-20	ISO 15118-20	ISO 15118-2 / ISO 15118-20	n.a.	ISO 15118-2 / ISO 15118-20	ISO 15118-2 / ISO 15118-20	n.a.	n.a.	IEC 61851 / ISO 15118-20	ISO 15118-2 / ISO 15118-20	ISO 15118-2 / ISO 15118-20
		Charger -EMS	OCCP 2.0.1	OCPP 1.6	OCPP 1.6, OCPP 2.0.1	OCPP 1.6 (simulated)	OCPP 1.6	OCPP 1.6-2.1	n.a.	n.a.	OCCP 2.0.1	OCPP 1.6-2.1	OCCP 2.0.1
		Charger -CPO	OCCP 2.0.1	OCPP 1.6	OCPP 1.6, OCPP 2.0.1	n.a.	n.a.	OCPP 1.6-2.1	n.a.	n.a.	OCCP 2.0.1	OCPP 1.6-2.1	OCPP 1.6, OCPP 2.0.1
		CPO - SCSP	OCPI 2.2	n.a.	***t.b d.***	n.a.	n.a.	OCPI 2.2	n.a.	n.a.	OCPI 2.2	OCPI 2.2	n.a.
		CPO - eMSP	OCPI 2.2	n.a.	n.a.	n.a.	n.a.	OCPI 2.2	n.a.	n.a.	OCPI 2.2	OCPI 2.2	n.a.

Annex 5. System architecture per use case