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Accelerating Smart Charging and V2X: experiences implementing pilots across Europe

A study based upon the experiences implementing the SCALE (Smart Charging Alignment for Europe) use cases demonstrating smart charging and V2X - Horizon Europe project

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Executive Summary

The paper describes the work done in the SCALE project on 13 smart charging and V2X use cases executed across Europe. The central activity in the project has been the implementation of use cases by adopting the SCALE principles of open standards and system architecture. Finishing in July 2025, SCALE is focused on preparing smart charging and V2X ecosystems for mass deployment. This paper presents the conclusions and learnings from the latter phases of the project, reflecting on the full range of charging services, energy services, system architecture and communication topology and protocols needed to fulfil upscaling potential in 13 charging contexts. Whereas smart and bidirectional charging present huge potential to unlock flexibility, with V2G technology the potential for such services is only further increased and this is of great interest.

1 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 (NL), Utrecht (NL), Eindhoven (NL), Toulouse (FR), 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.

2 Context of the use case implementation for upscaling

The paper describes how the use cases have been setup in accordance of the principles described in the Stakeholder Analysis Report[1], Analysis of hard- and software requirements[2] and Multi-actor Smart Charging & V2X System Architecture[3]. Through this framework key elements of the industry value chains, system architecture, control topologies and central communication protocols are connected to assess the success of the implemented integrated systems present in each use case.

The paper describes the use case evaluations assessing the implementation and execution activities carried out in the latter phase of the project. As part of this final phase, the paper reflects on the range of charging assets and services, energy services and system architecture needed to complete the upscaling potential of each charging context and associated mobility service. By wholistically assessing the interaction of business operations and technical facets of each service segment, in SCALE we can better understand the upscaling potential of smart charging and V2X on these different mobility services.

Looking at the various mobility services it is apparent that within the different use cases there is good representation of relevant services such as car-sharing; private - and company cars and in the heavy duty vehicles, B2B. In SCALE we aim to better understand the impact of these different mobility services on the smart charging and V2X potential. Figure 1 provides a graphical representation of the different locations of the use cases and therefore the national contexts.

Figure 1: SCALE - Use case locations

3 Industry value chains in scope

On the various charging services deployed in the use case a distinction is made between AC and DC charging. These two categories are further separated between unidirectional and bidirectional charging, and for DC charging also instant fast charging. There is good variation between the services that are deployed in the use cases, where many use case have more than one of these services included. In SCALE the energy services are grouped into 4 categories as illustrated in node 4 of figure 2 “industry value chains”, namely:

(1) Local behind-the-meter optimization
(2) Balance responsibility
(3) System balance
(4) Congestion management

Each of these categories is again subdivided into the specific energy services. An inventory of the planned energy services is provided for all use cases. All use cases are implementing “local behind the meter optimisation”. Besides that, many use cases are planning to implement energy services in the other 3 categories.

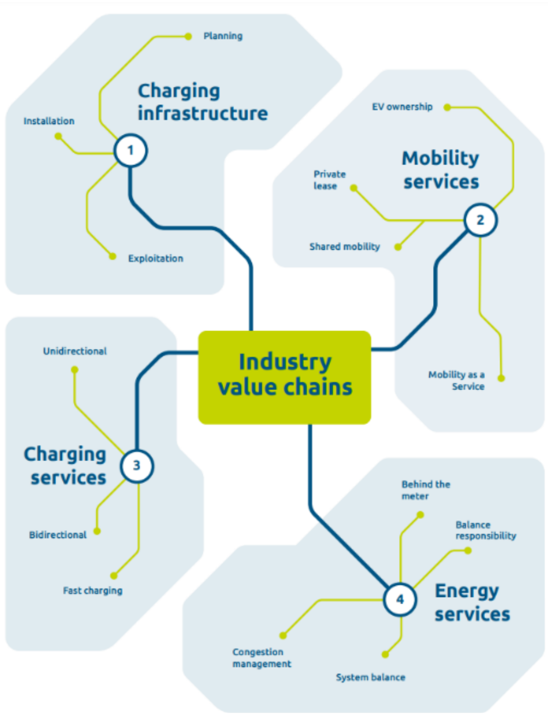


Figure 2: Industry value chains

4 System architecture and open standards

With smart charging or V2X there is one actor in control of the charging session. In SCALE there are three control topologies that can be distinguished: the car manufacturer (OEM), the Charge Point Operator (CPO), or the Energy Manager (EM). This is visualized in figure 3.

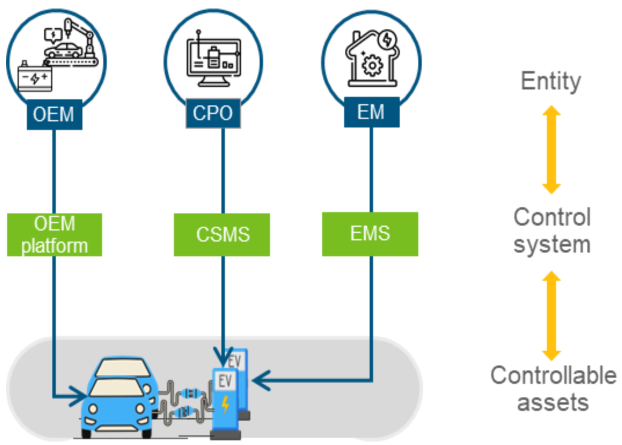


Figure 3: Control topologies

In the use cases and within the SCALE goals of implementing open standards and protocols only the CPO and EM control topologies are applied. SCALE aims to promote open standards and protocols that support smart charging and V2X in an interoperable manner. In the system architecture there has been much attention on communication protocols. In the report, for each use case it has been mapped which protocol and standards are implemented and their role in contributing to the objectives set is evaluated. Where, and how, these fit in, is exemplified in figure 4.

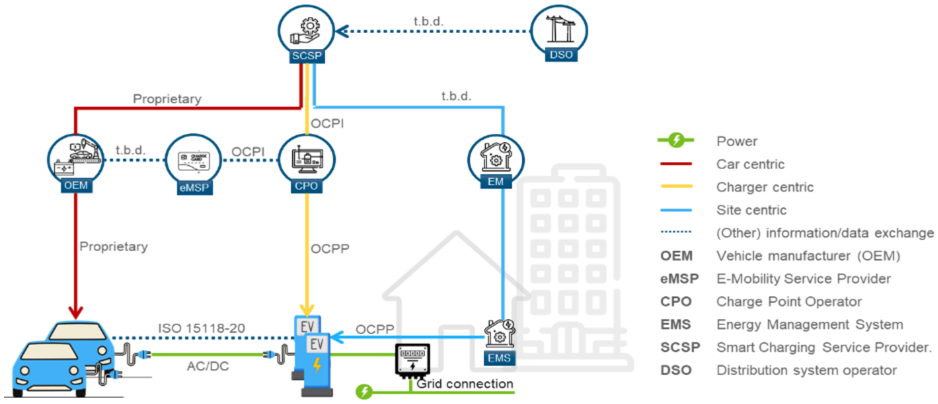


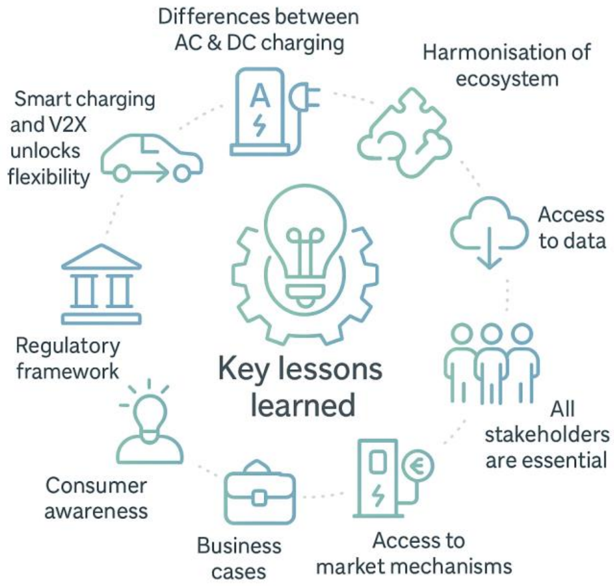
Figure 4: Example use case architecture on communication protocols

5 Key learnings & conclusions

In the last three years each use case followed three phases: preparation & set-up, execution & monitoring, and quantitative and qualitative data gathering. As we reach the end of phase 3 it is now possible to assess, extrapolate and cross-examine the findings from the different use cases and this was largely carried out in D3.2 Use case evaluation (Christiaens et al., 2025). To reach an higher abstraction level the evaluations have also been done on what has been defined as the innovation cluster levels, being:

(A) Smart home charging
(B) Smart charging at businesses/offices
(C) Smart charging of light and heavy-duty fleets
(D) Smart public charging.

As use case learnings 9 key topics where identified as provided in the below figure. These are further detailed in the full D3.4 report provided on the SCALE website.



The key conclusions that we can draw from these learning are summarised in relation to the implementation and further upscaling of smart and bidirectional charging solutions.

Smarter charging

Advanced smart charging solutions, as piloted in the SCALE use cases, can unlock significantly more flexibility compared to the smart charging that is mainstream today. In order to untap this potential, these technologies need to become mainstream. From our SCALE learnings, key topics for scaling up towards advanced smart charging solutions can be summarised into two key topics:

(a) the business case; getting access to market mechanisms so that advanced smart charging aligns with the dynamic needs in the electricity system and results in revenues so that the end user (and other stakeholders in the value chain) are incentivized to participate. It is important to realise that there is a lot of uncertainty on the business case around smart charging. High degree of variance of pricing in existing markets and differences between countries adds to this complexity.

(b) the harmonisation in the ecosystem to allow the highly needed transfer of data and the control of assets. In the heart of the e-mobility domain this is primarily about the adoption and maturity of ISO15118, OCPP 2.X. The hardware of the equipment (BEVs and recharging points) need to be capable to support these standards. Retrofitting existing equipment is often not possible. Harmonisation in the energy domain can further add to the flexibility potential. Integrations to access smart meters, (H/B)EMS, energy storage systems, flexibility markets are currently often tailor made solutions. This makes implementations complex and costly resulting in barriers in many use cases to implement.

Bidirectional charging

Bidirectional charging can be seen as an add-on to advanced smart charging. It introduces more potential to offer flexibility in the electricity system, but is also faced with some additional challenges. These are;

(a) The business case; further to the above it is important to remove regulatory barriers like double taxation and feed-in tariffs that exist in some countries. These are prerequisites to a positive business case.

(b) Further to the harmonisation in the e-mobility ecosystem it’s important that both vehicles and recharging points are hardware capable for bidirectional charging, support the latest standards (ISO15118-20, OCPP 2.1) and are software enabled to allow bidirectional charging. With the latter often not possible due to immaturities around interoperability, the possibility to remotely update to the latest protocols and enable bidirectional charging is probably the best viable option for these manufacturers today.

(c) Network code complexity for bidirectional charging present challenges for the implementation of V2X technologies. These challenges are primarily related to AC charging where typically the combination of the CP and EV needs to comply with these codes. As there are numerous configurations between EV and CP possible and since EVs can cross borders with implications on which national grid codes to comply to, there is a clear need to revisit the regulatory framework to allow V2X on full scale.

Knowing the complexity of implementing smart and bidirectional charging today, there are differences in this complexity from cluster to cluster. The below provides an overview of these differences.

Continued efforts to upscale

At the present level of maturity on advanced smart charging and bidirectional charging it is clear that we’re far from a fully open and interoperable ecosystem. There is a clear need to continue to upscale with implementations to further enhance the maturity level. By different implementations across a variety of use cases the different stakeholders can all make their contributions and progress together to overcome the addressed challenges of today.

From SCALE and the previous chapter it is apparent that there are important differences between the innovation clusters. In certain clusters, commercially viable concepts on smart, but also on bidirectional charging already exist today. In the table below an overview of today's key challenges faced by smart and

Innovation Cluster	Immature interoperability	Stakeholder complexity	Network code complexity (V2X)
A: Smart home charging	+	+	+
B: Smart charging at businesses/ offices	-	-	- -
C: Smart charging of light and HD fleets	0	+	+
D: Smart public charging	- -	- -	- -

bidirectional charging are provided in relation to the 4 innovation clusters.

(++) not an issue <---> significant issue (- -)

Important to mention here is that all the key challenges are related to both smart - and bidirectional charging with the exception of the "network code complexity" which is on bidirectional charging. What can be concluded from the table is that barriers to implement advanced smart charging solutions in business and offices (IC-B) and for public charging (IC-D) faces higher challenges. It's also visible that there are "low hanging fruit" clusters such as home charging (IC-A) and to a lesser degree charging of light and heavy-duty fleets. This is also visible in some of the commercial solutions offered by OEMs today. These solutions are often closed setups with no or limited variance between the type of EV, CP and EMS to avoid interoperability issues. Nevertheless they have adopted the open standards, contribute to the learnings of its use and therefore to further mature it. Also these "low hanging fruit" clusters can serve as a stepping stone to learn from and improve the business cases around the various use cases in these innovations clusters. This is also likely to result in more momentum for the less progressive stakeholders to advance their efforts and take part in the smart charging and V2X ecosystem. Examples of these stakeholders include manufacturers of CPs or BEVs whom currently do not see a clear market for advanced smart charging and bidirectional charging.

For the innovation clusters B and D it is apparent that there are showstoppers hindering the commercial roll out today. More experimental pilots are needed or solutions have to be investigated in specific use cases with shared electric cars like in SCALE. Conducting those pilots creates momentum for more manufacturers and other stakeholders aim their efforts at maturing their technologies and unlock use cases in these innovations clusters.
For more detail on the methodological framework, key learnings, and the conclusions in full, we refer to the complete report in which these are provided.

For more the full reports of the SCALE use case results see D3.2 - Use Case evaluation report & D3.4 Lessons learned report on the scale website (https://scale-horizon.eu/publications).

References

[1] Langenhuizen et. al: Stakeholder analysis – SCALE Project deliverable D1.2 https://scale-horizon.eu/publications/ (2022)

[2] Meersmans, Jelle: Analysis of hard- and software requirements – SCALE Project deliverable 1.5 https://scale-horizon.eu/publications/ (2023)

[3] Christiaens et. al: Use case setup report – SCALE Project deliverable D3.1 https://scale-horizon.eu/?jet_download=605 (2023)

Presenter Biography

	**Edwin Bestebreurtje MSc** is partner and senior consultant of FIER Sustainable Mobility. Edwin has been specialized in business development projects in the automotive and mobility sector. He was responsible as project manager for developing the Automotive Campus in Helmond and project manager in European projects on (e-) mobility, such as SOLUTIONSplus, SCALE and GEMINI. Edwin is responsible for the European Alternative Fuels Observatory (EAFO) which is THE knowledge platform for alternative fuelled transport in Europe owned by EC DG Move.