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SCALE EU Horizon project Optimization of Charging Strategies in Depots for Electric Vehicle Grid Integration

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Executive Summary

This work aims at optimizing charging strategies within logistician depots to facilitate electric vehicle (EV) grid integration in case of massive future uptake of EVs. Scenarios ranging from 100 to 500 EVs to be daily charged are simulated with and without smart charging (shifting some charging sessions to night times). The paper presents the used methodology, assesses the impact of smart charging through electricity consumption load curves for the various scenarios and provides ROI evaluation. For every scenario, the additional needed power capacity is reduced by 50% when smart charging applied.

Keywords: Electric Vehicle, smart charging, energy management, smart grid integration and grid management, charging business models

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/Utrecht (NL), Eindhoven (NL), Toulouse (FR), Budapest/Debrecen (HU) and Gothenburg (SE). For more detail see the website [Home - SCALE](scale-horizon.eu) (scale-horizon.eu).

The French demonstration, conducted in Toulouse, takes place at a vehicle depot where the share of electric vehicles (EVs) in the fleet (composed mainly of light passengers thermal cars) is steadily increasing each year. This use case aims to analyze the existing on-site charging infrastructure and project the required power capacity for future scenarios, characterized by a significant increase in fleet electrification. 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.

As a Distribution System Operator, we are looking at optimizing charging strategies within logistician depots to facilitate electric vehicle (EV) grid integration in case of massive future uptake of EVs. 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 similar sites which are numerous in the territory and get ready for a fair power increase at a proper localization.

More specifically, this study focuses on:

- Preventing the need for further grid reinforcements by optimizing the required power capacity to accommodate future EV fleets.
- Identifying the optimal charging strategy through simulation.
- Motivating Smart charging from ROI and energy bill perspective.

The following paragraph describes the current situation and charging habit on the logistic site. The next paragraph describes the methodology employed for smart charging strategies and simulation results are illustrated through electricity consumption load curves for the various scenarios and charging strategies considered. The fourth paragraph describes ROI (Return On Investment) methodology from charging infrastructure perspective and evaluates the savings through energy bill.

2 Current situation

The use case takes place at a car park depot in Toulouse, France, where cars (light passengers and vans, mostly thermal cars) are stored. Fir about 10 year the site accommodates EVs, where the share is increasing steadily. The customers for storage services are either OEMs for new car storage or renting agencies for their fleet maintenance or renew. The EVs need to be charged before being delivered somewhere else.

With regards to EVs, the onsite chargers are used by the staff to charge EVs that must be charged from 50% to 100% SOC before being delivered (the average in 2023 is about 10 to 30 EVs to be charged per day). The EVs are driven to be parked next to the charger place. For safety reasons it is recommended to charge only when employees are present. This means they can't plug and leave the EVs charging after the working hours, nor scheduled to night times. The current electricity contract is a fixed price one (as usually this site does not consume by night, neither the Weekends). Up to now, the share of EVs among the fleet is quite low, and there is no significant benefit to shift to ToU (Time of Use), as in case of ToU the peak time prices are higher than the baseline tariff (fixed).

The first part of the study involves an analysis of electricity consumption load curves over different years, seasons, and times of day.

1.1 Reference - year 2023- Consumption Data Analysis

The consumption data are collected after consent permission provided by site owner on it's point of delivery.

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).

This consumption is measured for all usages of the site, including maintenance machines, heat, and EV charging sessions. The year 2023 has been tracked for a full site consumption analysis. The figure 1 below provides the minimum, the maximum and averages for the whole year. The idea is to use this reference to make comparison with future simulated scenarios. Site's team has been installing chargers for almost 10 years and is looking constantly at the best solution to provide the charging service at a best balance between need and investment of chargers for its fleet: AC or DC and for what power capacity, with an uncertainty for future EV penetration.

In 2023, there was few 7,4 kW and some new 22 kW chargers (in total 8 chargers were available). The power capacity contract has not been modified, as for high customers the power capacity can be above without any alert neither power cut. However, penalties are applied in case of power overloading above the subscribed limit.

Legend

- Orange: subscribed power contract (fixed in kW)
- Red: maximum used power (in kW)
- Grey: average used power (in kW)
- Blue: minimum used power (in kW)

The figure 1 below illustrates the used power capacity (in kW) per time step of 30 min for each day of the year (here 2023).

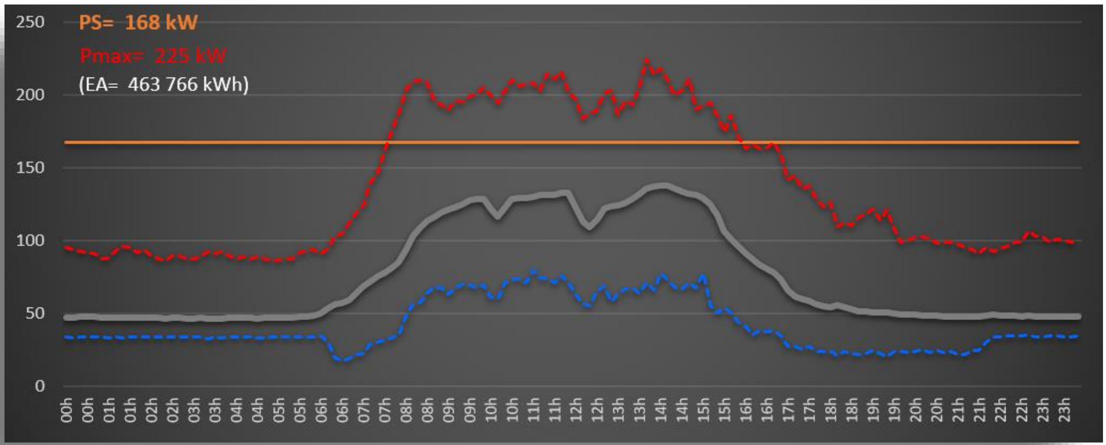


Figure 1: Reference 2023 –Site consumption per working day including EV charging session (10-30 EVs)

1.2 Site Consumption evolution

The figure 2 below, shows the impact of charging consumption from year 2019 to June 2024 the total energy consumed is increasing over the years (due to increasing charging sessions) maximum power spread seems to increase over the years, more specifically the gap in 2022 is quite significant, while averages are steadily increasing. Max power and average consumption in working days (7am – 5 pm).

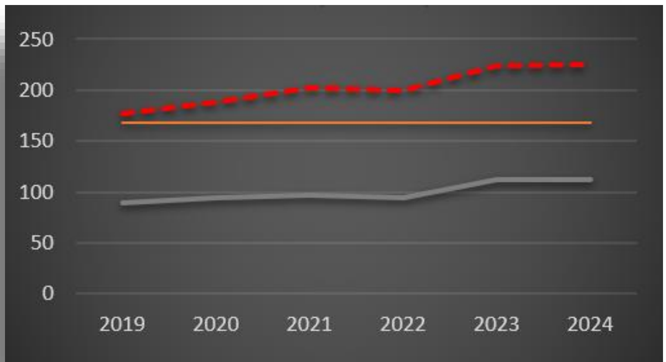


Figure 2: Site Consumption evolution from 2019 to June 2024

3 Simulation results for future scenarios

Here, we forecast future demand by simulating three scenarios for daily electric vehicle (EV) charging fleets. We analyze 3 major scenarios: 2023 + 100 EVs; 2023 + 250 EVs; 2023+500 EVs).

The modelling is based on a mix of chargers of 7,4kW and 22kW. The model adds chargers and stops when the targeted SOC (100%) is satisfied for all EVs. The initial SOC is randomly modelled.

Simulation results indicate that utilizing off-peak charging periods (both day and night) reduces the required power capacity by 50% (see green lines in Figure 4, 6, 8), compared to maintaining charging exclusively during daytime hours (yellow line).

Legend

- Yellow: dumb charging (plain: average, dots: maximum)
- Green: with smart charging (plain: average, dots: maximum)

Scenario 1 – 2023 + 100 additional EVs per day

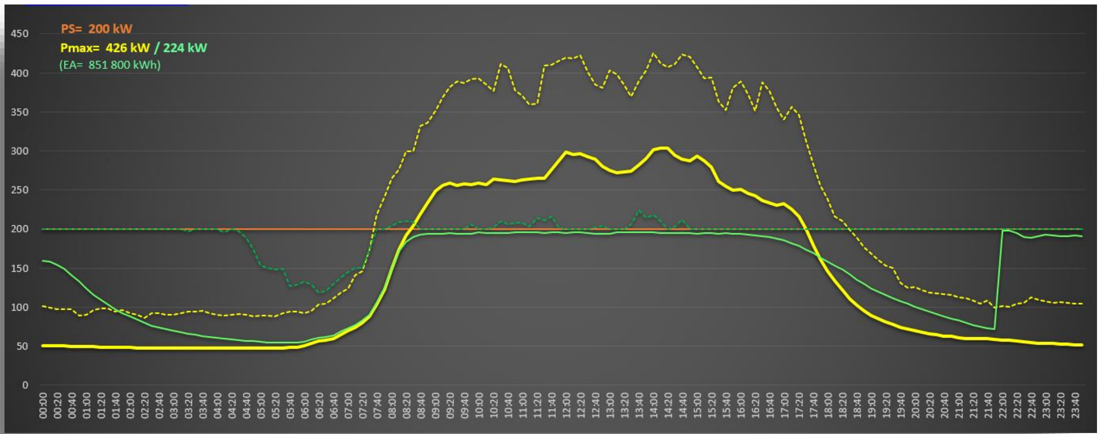


Figure 3: scenario1 - yearly maximum power capacity (dots) and average (plain)

Figure 4: scenario1 - Weekly Load curve starting 18 December 2023

Scenario 2 – 2023 + 250 additional EVs per day

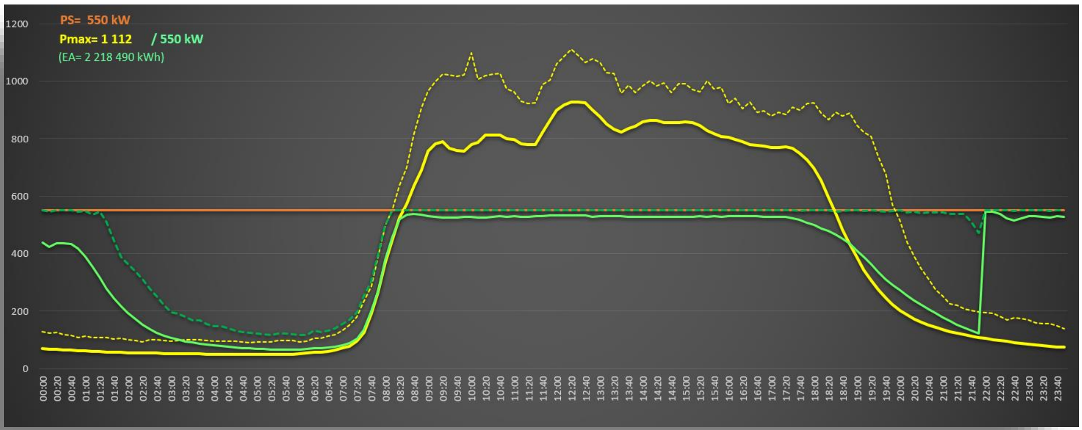


Figure 5: scenario 2 - yearly maximum power capacity (dots) and average (plain)

Figure 6: scenario 2 - Weekly Load curve starting 18 December 2023

Scenario 3 – 2023 + 500 additional EVs per day

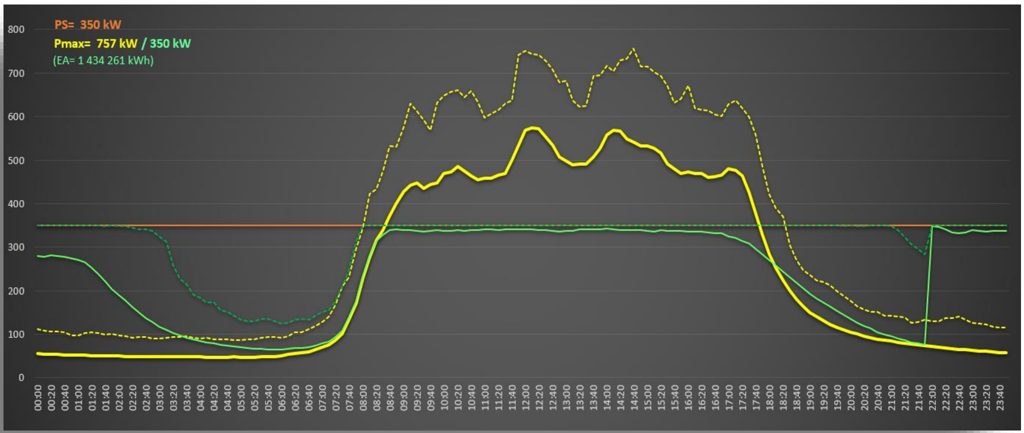


Figure 7: scenario3 - yearly maximum power capacity (dots) and average (plain)

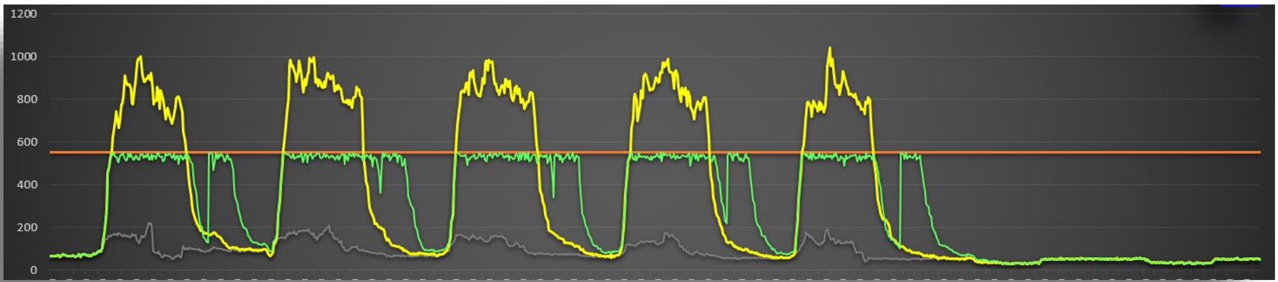


Figure 8: scenario3 - Weekly Load curve starting 18 December 2023

4 Return On Investment

A return on investment (ROI) analysis was undertaken for the **'2023 + 250 EVs' scenario**. The results from this scenario showed that over the course of the modeled year the smart charging profile could save €19,487 in energy costs compared to the dumb charging profile. This is predominantly driven by the shifting of charging away from the peak day tariff to the off-peak tariff, with additional small proportion due to a reduction in the amount of penalty fees paid for peak consumption above the subscribed limit.

The variable component of the electricity tariff used in the modeling are taken from the French residential regulated tariff – as commercial and industry tariff rates are considered commercial-in-confidence information and was not provided for our project. The following rates were used:

- Peak winter: 18,29 c€/kWh
- Off-peak winter: 10,29 c€/kWh
- Peak summer: 9,05 c€/kWh
- Off-peak summer: 4,67 c€/kWh

Applying these rates to the modelled data for the '2023 + 250 EVs' scenario yielded the €19,487 savings in electricity costs by smart charging compared to dumb charging. However, the smart charging scenario required a larger number of electric vehicles charging points. In this scenario, 198 charging points were required for smart charging compared to 139 for dumb charging – a difference of 59 charging points. With the exception in their numerical difference, the charging points used for both smart and dumb charging are in all other respects the same hardware with the same installation setup.

Based on this, the smart charging use-case can be considered as an investment that gives an annual return. The annual return is approximately €19,500 – corresponding to the savings in charging costs based on the 2023 modelling. The investment cost is the additional cost of the 59 chargers required to enable the smart charging setup. We can assume the purchase and installation costs of the chargers to range from €1000 - €1500 per charger. We can also adopt two different investment time horizons, of 5 years and 7.5 years. From this we get 4 different ROI scenarios based on the following assumptions:

<table>
<tr><td>ROI Scenario 1a
• Investment period: 5 years
• Cost per charger: €1000</td><td>ROI Scenario 1b
• Investment period: 7.5 years
• Cost per charger: €1000</td></tr>
<tr><td>ROI Scenario 2a
• Investment period: 5 years
• Cost per charger: €1500</td><td>ROI Scenario 2b
• Investment period: 7.5 years
• Cost per charger: €1500</td></tr>
<tr><td colspan="2">Common assumptions:
• Cost per charger includes all costs associated with charger purchase and installation
• The chargers are assumed to have zero investment value at the end of the investment period
• The total investment cost is the cost per charger multiplied by 59 – as this is the additional amount of chargers needed for the smart charging use-case.
• The investment provides an annual return of €19,500 – corresponding to the savings in charging costs from smart charging.

Sensitivity considerations:</td></tr>
</table>

- +/- 30% in the annual return of €19,500
(+30% gives €25,350
-30% gives €13,650)

The basic formula for ROI calculation is used:

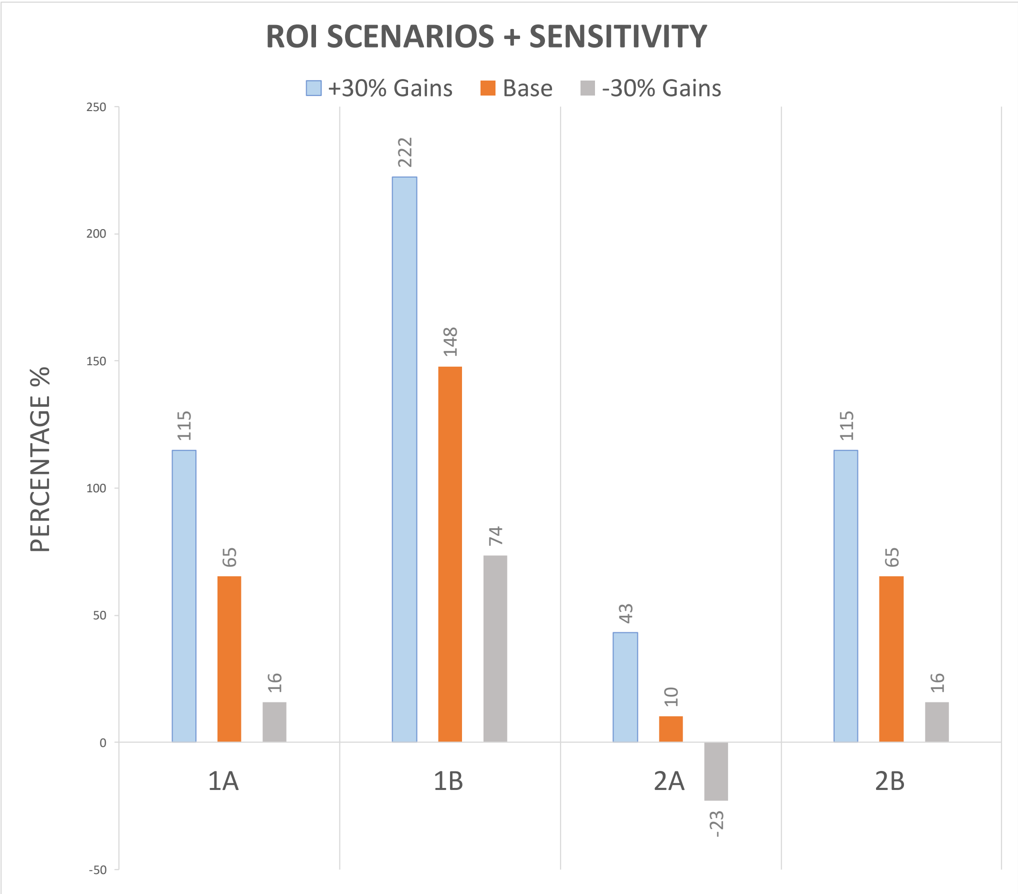
ROI (%) = ((Total Return − Initial Investment) ÷ Initial Investment) × 100

Where:

Initial investment amount corresponds to 59 (the number of additional chargers required for smart charging compared to dumb charging) multiplied by the cost per charger.

Total return is the annual savings from smart charging compared to dumb charging multiplied by the number of years in the investment period.

With the above assumptions in place, we calculated a range of ROIs ranging from -23% in the worst case to 222% in the best case. These are reflected in the diagram below.



As can be expected, a low initial investment cost (i.e. charger purchase and installation) has a major impact on the return on investment. As the per unit charger purchase and installation price reaches €1500, the ROI over a 5-year time horizon risks becoming negative if the annual savings from smart charging drops by 10% or more. Another insight that can be drawn is that by extending the time horizon 50% (from 5 years to 7.5 years) the ROI can be doubled. Therefore, emphasizing that the longevity and reliability of the chargers could be an important consideration to take into account. Given a 7.5 year investment time horizon, the ROI in the high initial investment cost scenario (2b) is still positive at 16% even if the predicted €19,500 annual savings from smart charging drops by 30%. We should bear in mind that if smart charging option is chosen (with larger number of chargers), there will be less need for labor, as EVs will not be moved several times. Some additional savings in labor costs are also expected, however not included in this analysis.

The table below shows the calculated ROI for each scenario, including the compound annual growth (CAGR) ROI rate.

Sensitivity Analysis - ROI and CAGR

#	Scenario	Case	Adjusted Annual Gain (€)	Simple ROI (%)	CAGR (%)
1	1a	Base	19500.0	65.25	10.57
2	1a	+30% Gains	25350.0	114.83	16.53
3	1a	-30% Gains	13650.0	15.68	2.96
4	1b	Base	19500.0	147.88	12.87
5	1b	+30% Gains	25350.0	222.25	16.88
6	1b	-30% Gains	13650.0	73.52	7.62
7	2a	Base	19500.0	10.17	1.96
8	2a	+30% Gains	25350.0	43.22	7.45
9	2a	-30% Gains	13650.0	-22.88	-5.06
10	2b	Base	19500.0	65.25	6.93
11	2b	+30% Gains	25350.0	114.83	10.73
12	2b	-30% Gains	13650.0	15.68	1.96

5 Conclusion

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. The related energy bill is also reduced, and ROI analysis advised to choose a long-term investment strategy for chargers' investments.

Acknowledgments

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Presenter Biography

Karima is currently senior consultant on electric mobility within the French DSO, Enedis. Before joining Enedis in 2015, she was head of future grids activities within EDF Energy based in London. Karima holds a PhD in mathematics from Pierre & Marie Curie Paris University.