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Behavioural Insights into Smart EV Charging: Advanced Experiments at the JRC Ispra Living Lab for testing Digital Energy Solutions

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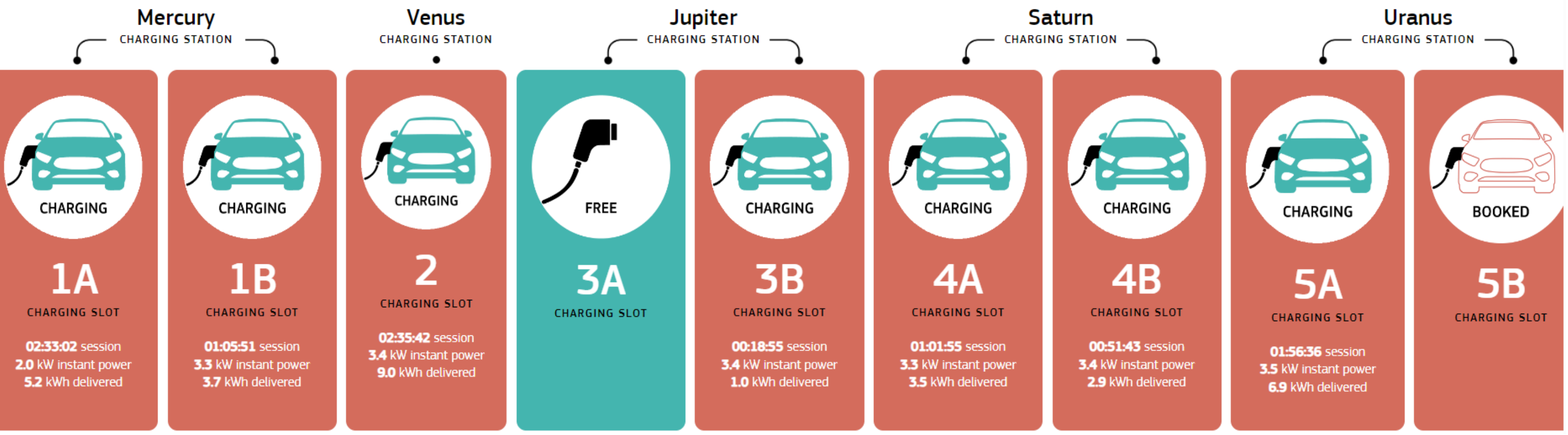

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Contents

Abstract

In an effort to anticipate innovative solutions for policies related to the European Green Deal on areas such as smart grids, demand response and renewable electricity integration into the grid, in the last 2.5 years the JRC Living Lab for testing Digital Energy Solutions (hereafter referred to as DES-Lab), operating within the SMARTEN work programme project, has been conducting research by testing and deploying smart charging systems for EVs and on their impact on the use by staff on JRC sites.

Using PRISM, a customisable EV-charging wallbox provided by an Italian start-up, the research aimed at studying the impact of smart charging systems on user experience and staff's use-case specific behaviour; specifically to investigate the behaviour and choices of staff EV owners in response to various incentive schemes for utilising a workplace charging station.

The experimentation rounds in 2023 highlighted a number of issues concerning the behaviour of an exemplary client group and their use of the charging stations, particularly the prolonged undue occupancy of the charging points, which is not easy to manage in workplace-charging situations.

These findings stressed the need for improved user coordination, better adherence to the rules for fair use of the chargers, and better insight, as well as greater awareness of the optimal charging timing to maximise the use of renewable energy.

Whilst the use of targeted communication with users had limited impact on their behaviour, the implementation of authentication and credit-point schemes proved to be more effective in addressing behavioural issues, even though the effects of the more elaborate credit-point scheme appeared to affect mainly those consumers most intensively using the charge field.

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Finally yet importantly, the DES-Lab team would like to express gratitude to all EV users onsite the JRC Ispra, for their active participation and engagement.

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1 Introduction

The full integration of renewable energy sources in the energy mix and secure energy supply in the European Union are crucial elements in the **modernisation and expansion of the EU's energy infrastructure**, which are paramount to achieve the European Green Deal's [1] climate and energy goals. In order to compensate for intermittent availability of renewable electricity, flexibility elements linked to the power grid, like controllable load portions from *smart electric vehicle charging*, are becoming a focus of attention.

To contribute to the objective of improving the EU's charging infrastructure for electric vehicles (EVs), in the last 2.5 years the Living Lab for testing Digital Energy Solutions (DES-Lab) at the JRC site in Ispra, Italy has been conducting research aimed at **testing and deploying smart charging systems for EVs and the impact of their use-case schemes on the utilization by staff**.

The present study investigates the **behaviours and choices of EV owners** in response to various **incentive schemes** for utilising a workplace charging station, offered in a charge field within the work-site. In this respect, the **involvement of JRC staff** has been fundamental in allowing to gather anonymised, but meaningful charging sessions' data to feed the research. Anonymised data from users are given to DES-Lab on a voluntary basis, while free electricity is provided to staff by the JRC Ispra site management to recharge their private cars, as part of the scientific experimentation.

The project aims to anticipate solution paths and pre-normatively researches for policies related to the European Green Deal on areas such as smart grids, energy efficiency, local energy markets, and environmental sustainability monitoring.

By investigating the impact of smart charging systems on user experience and workplace's staff behaviour as well as assessing the implications on a workplace's or site's environmental footprint, the project aims to provide valuable insights that can inform and **support the EU's efforts to achieve its climate and energy goals.** In particular, the project may have impact on the following areas, as foreseen in [2]:

1. **Grid management for e-mobility / Grid-services from e-mobility**: Understanding EV users' charging behaviours and patterns can support utility companies and distribution grid operators in better managing the electricity grid. Identification of peak charging times and load distribution contributes to more efficient grid operation and load balancing, potentially reducing the risk of overload on the grid or unwanted power curbs during high-demand periods. Knowledge is collected to shift charging times to periods of abundant availability of renewable electricity, whilst not reducing the quality-of-service to the EV-owners.

2. **Infrastructure planning**: Charging sessions' data analysis can provide valuable insights into usage patterns and demands for EV charging, to assist in the strategic planning and development of the charging infrastructure with useful data in the geographical, social and behavioural dimensions. Investments into strengthening the distribution grid, where necessary, can be better quantified.

3. **Energy efficiency and demand response**: Information on energy consumption patterns can support the development of strategies for energy efficiency and demand response programs. Incentivising EV charging during off-peak hours or encouraging user participation in load-shifting initiatives contributes to a more sustainable and cost-effective use of energy and infrastructural resources. Also the communication between the charging infrastructure and

the vehicles, as well as with the distribution grid can be more or less cost- and energy efficient, and is optimised by practical lessons learned.

4. **Policy and regulation**: The insights gained from user behaviour and charging data analyses has already and will provide evidence-based recommendations for specific guidelines, standards, and ultimately, the development of policies and regulations. This would promote EV adoption, encourage the expansion of the charging infrastructure, and support renewable energy sources integration into the grid by flexible load compensation.

5. **User experience and EV adoption**: Identifying weak points in semi-public charging offers (like work-place or clientele specific offers), optimizing charging processes, and addressing user concerns can enhance EV owners' satisfaction levels, thereby promoting wider EV adoption.

The project exploits **PRISM**, a customisable wallbox for smart EV charging that allows users to tailor charging services to their specific needs. The PRISM wallbox also enables smart charging using electricity generated by a connected photovoltaic (PV) system.

PRISM is a product of the Italian start-up Silla Industries, with whom the JRC has signed a collaboration agreement for testing and deploying the PRISMs chargers in pre-normative research for smart charging approaches.

After extensive testing the PRISM technology in the lab, this publication now reports about the experimentation rounds with the users in real implementation, carried out by DES-Lab from March 2023 to December 2023, and discusses the key findings from these rounds, including collaborative efforts with JRC Unit S.1 - Competence Centre on Behavioural Insights.

The report also includes a short summary of the previous experimentation rounds from September 2022 to February 2023. Further details on these rounds are available in [3].

This report is organised in sections, with Section 2 outlining the project's objectives and main features, Section 3 providing a detailed description of the different experimentation rounds and research outcomes, Section 4 outlining the project's next steps and planned developments, and Section 5 containing the conclusions.

2 The EV charge-field at the JRC Ispra

The collaboration agreement

The smart EV-charging stations research project has been enabled by a non-monetary collaboration agreement between JRC and the Italian start-up Silla Industries (formerly known as Cartender). As successful applicant to JRC's Call for expression of interest, Silla Industries had signed a 72-month collaboration agreement due to expire on 24.09.2026 for testing and deploying PRISM, a smart solution wallbox for charging EVs, at the JRC Ispra site as part of the site's modernisation plan.

The experimental research project was conducted and coordinated by the JRC Living Lab for testing Digital Energy Solutions of the *Energy Security, Distribution and Markets* Unit (C.3).

In addressing specific EV-wallbox interoperability challenges, the DES-Lab team received valuable technical assistance from the European Interoperability Centre for EVs, Smart Grids and Smart Homes, under the leadership of the *Sustainable, Smart & Safe Mobility* Unit (C.4). The Infrastructure Unit (R.I.4) at JRC Ispra also provided support for the identification of the parking location and the electric cabling. The Advanced Computing & ICT Services Unit (T6) provided ICT support.

What is PRISM?

PRISM is an open solution wallbox for smart AC-charging of electric vehicles, i.e., a charging system that allows the customisation of charging services by the implementer, according to specific needs, users and use-cases. In particular, PRISM allows smart charging using electricity produced instantaneously by a photovoltaic (PV) system connected to the local grid. JRC realised its own specific web-solution for monitoring the charging process thanks to the capability of the PRISM to measure and report the real-time charging power to an outside system.

A PRISM wallbox may be equipped with either one or two charging connectors, and therefore one single such device may allow for the charging of two electric vehicles simultaneously.

Installation of the PRISM charging points

Before proceeding with the installation of the PRISM chargers at JRC Ispra, laboratory tests on energy stand-by consumption, interoperability (including latency of EVs to adapt to changed current signals from the PRISM) and EMC (electromagnetic compatibility) were undertaken. A feasibility study was then performed in collaboration with JRC Unit R.I.4 to identify the most suitable location. The parking area located in the JRC Ispra site internal road "via Grecia" was selected, as it is also equipped with a wide PV plant covering the entire car park, and thus robust poles and cabling possibilities next to each parking spot were already pre-existent.

Nine charging points (for a total of five PRISM wall boxes) were installed (Figures 1a-1b), each with an individual nominal power of 32 A (7.4 kW) single phase.

Figure 1a. Parking area in the JRC Ispra site internal road “via Grecia” equipped with PRISM chargers.

Source: JRC DES-Lab, 2023

Figure 1b. PRISM wallbox serving two slots in the parking area.

Source: JRC DES-Lab, 2023

Objectives and purpose

Overall, the DES-Lab research project aims to:

- Provide data from a real-world setup, useful for EV charging districts in possible scale-up and for identifying best practices in smart workplace-charging and ultimately, smart cities.
- Collect sound data on many different EV models' responses to dynamically managed supply conditions.
- Build user experience and explore collective behaviour patterns for managing charging electricity demand during typical work time schemes, in order to maximise the number of successful charging sessions and electricity supply service, while minimising the duration of undue occupancy of the chargers by EVs already charged up, for instance.
- Test and validate methodologies to help mangers identify suitable motivation means to have all participants adhering to the rules, and billing options for future electricity supply to their staff.
- Apply cost-benefit analysis tools to assess whether more charging points, as well as more storage systems for renewable energy sources, could best fit the needs of an urban district.

JRC staff involvement and rules for a fair and safe use of the charging stations

By its nature, a Living Lab research project entails the involvement of a community. In this project, the JRC Ispra staff was encouraged to participate while free electricity is provided to staff by the JRC site management to recharge their private cars, as part of the scientific experimentation. Participation was voluntary, and individuals with a fully electric or plug-in hybrid vehicle had to agree to the Living Lab defined terms of use before taking part. Most important in this context were protection of personal (user-specific) data, and rules of conduct when using the charge-field. Both terms of use and rules of conduct were prepared by the DES-Lab team, whereas data protection rules were agreed with the Data Protection Office.

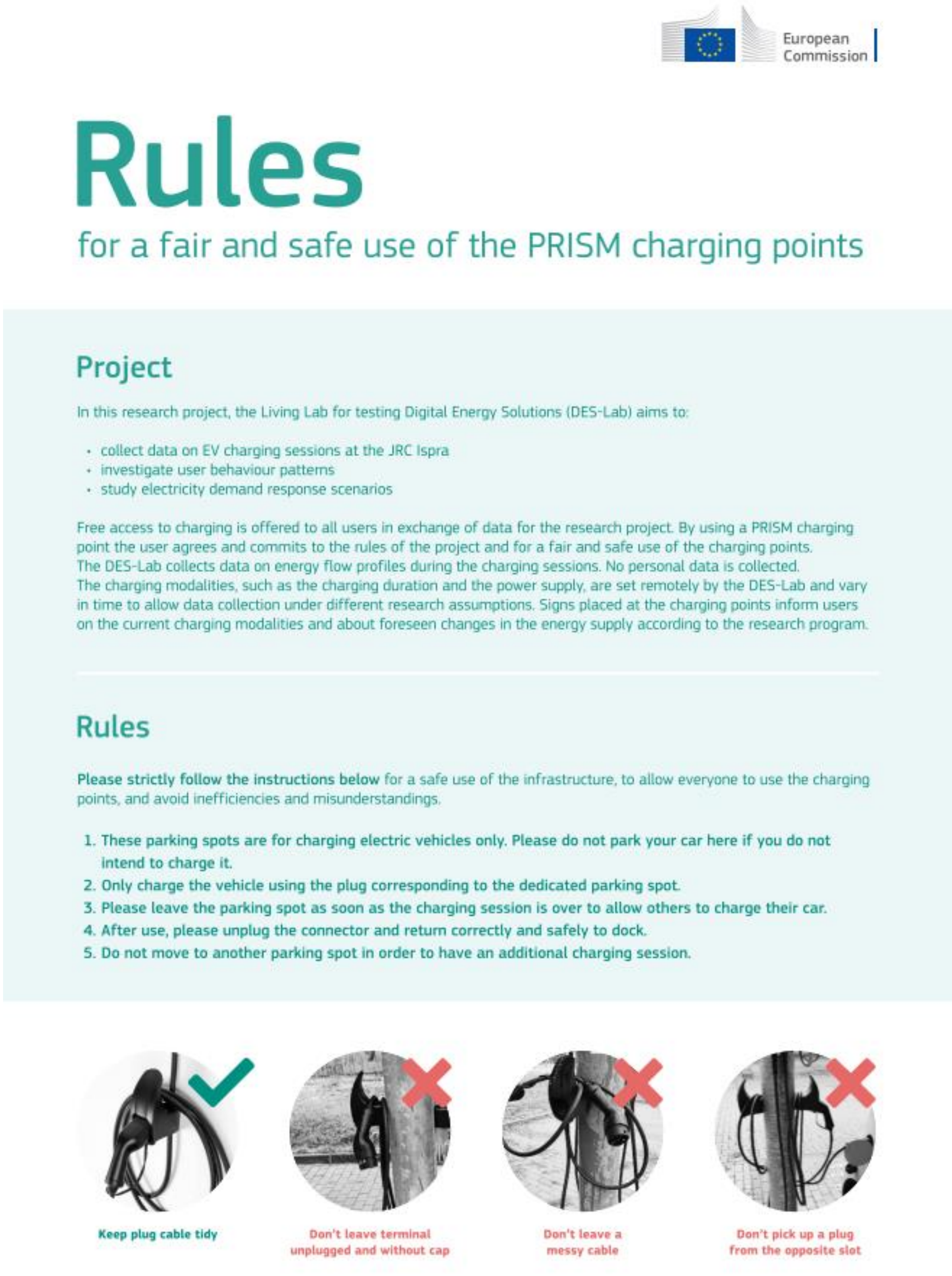
The DES-Lab team initially communicated that no personal data would be collected in the early stages of the project, ensuring complete anonymity to the users. As the project progressed, a registration scheme was introduced to enable more advanced analysis, always ensuring that personal and user-specific data was treated in accordance with privacy rules and agreements.

A set of rules of conduct was established to create a fair and safe environment for everyone involved in the project, i.e. charging her or his electric vehicle. The rules included:

- Allowing only one charge per day;
- Setting a maximum time limit for each charging session (this limit-value later being varied during the course of the project);
- Requiring car owners to promptly move their vehicles once the charging was complete, or the maximum charging time was over.

To inform and promote compliance with the established rules, the DES-Lab team implemented and tested consistent communication strategies. These included sending out regular e-mails to the user community, posting information on the former JRC intranet ("Connected"), and placing signage at the charge-field (Figure 2).

Figure 2. First signage positioned at the PRISM charge-field prepared by DES-Lab.



Source: JRC DES-Lab, 2022

As of December 2023, 125 JRC Ispra colleagues had agreed to participate to the smart charging research project.

Data gathered per charging session and session modalities

The initial data stored and analysed by DES-Lab included:

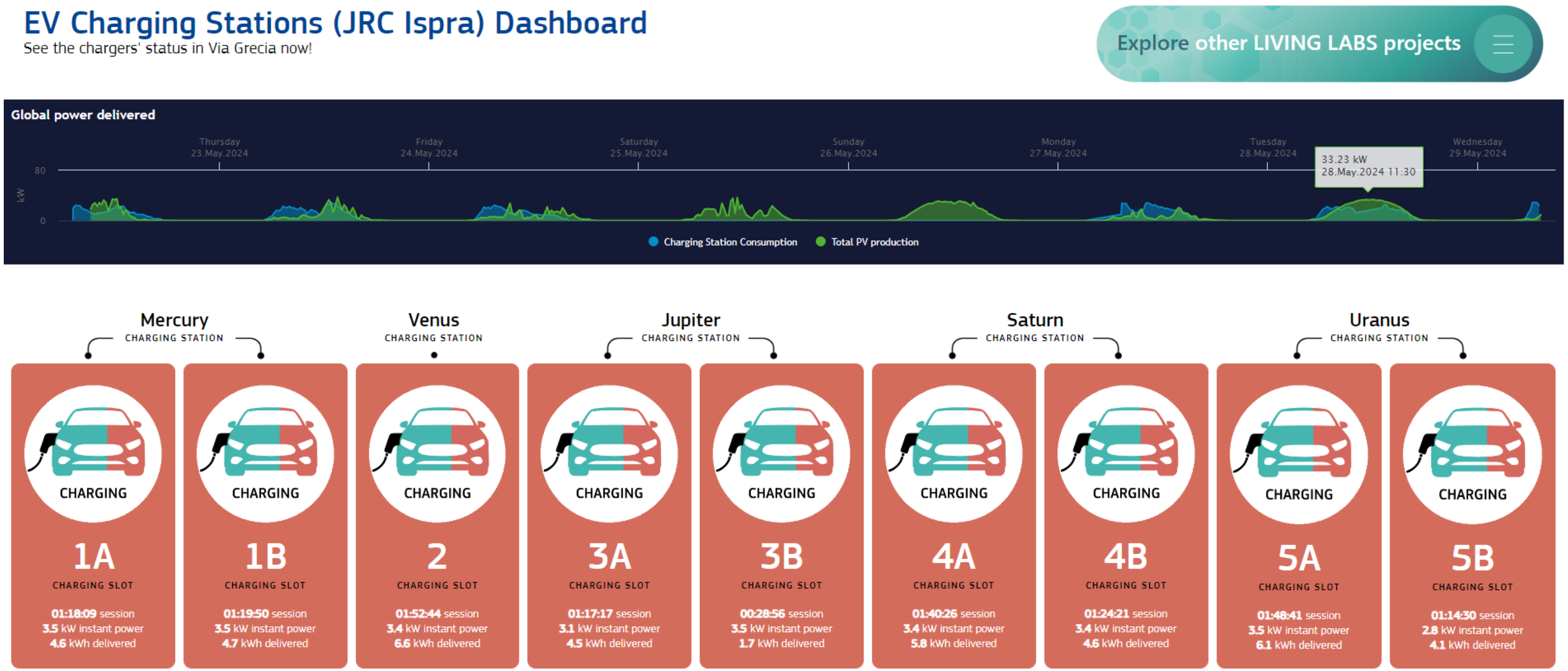
- The status and availability of the chargers;
- The starting and ending times of charging sessions, and therewith the overall session duration (in seconds);
- Instant power readings every minute (in kW);
- Total energy supplied during each session (in kWh).

The charging settings (maximum delivered power and session maximum time-length) were established by the DES-Lab team, and were later varied to facilitate data collection for different research scenarios. For more information on the experimentation phases and key findings, please refer to Section 3.

Dashboard / data visualisation

The DES-Lab team created a dedicated online dashboard (Figure 3) to provide real-time information on the charger availability, session duration, and energy delivered. These data are accessible to all staff members via the JRC Ispra internal network and can be online viewed live at https://energylab.jrc.cec.eu.int/prism/.

Figure 3. Dashboard for real-time information on EV charging sessions.



Source: JRC DES-Lab, 2023

3 Real-world experimentation rounds

The first round of "real-world" experimentations at the semi-public charge-field took place from September 2022 until February 2023, and information on the supply conditions and session outcomes can be found in [3].

Subsequently, from March until December 2023, the DES-Lab team collaborated with the JRC EU Policy Lab: Foresight, Design & Behavioural Insights (Unit S.1), to conduct a second series of experimentation rounds.

The following paragraphs offer detailed analysis of these experimentation rounds.

3.1 Summary of experimentation round #1 (September 2022 – November 2022)

The first experimentation round of the project spanned 9 weeks, from 12 September until 18 November 2022, operating under a **static supply modality.** This approach involved using a predefined set of values for the energy delivered and the maximum charging time allowed.

A summary of the experimentation round's features is provided in Table 1.

The experimentation round #1 was structured into three blocks, each block lasting for three weeks, and keeping supply conditions stable for those three weeks. The primary objectives were:

- to observe users' behaviour in response to different electricity supply conditions within each 3-week block; and
- to test the effectiveness of different communication means on reaching the users and influencing their behaviour across the three 3-week blocks.

Each three-week block featured the implementation of an increasingly explicit communication campaign to inform users about the rules for using the charging points. This campaign included posts on the JRC "Connected" intranet and visual signs at the charge-field, providing details about the project's research objectives, modalities, and guidelines for the efficient and safe use of the PRISM charge-points.

Two Key Performance Indicators (KPIs) were used to assess the progress and effectiveness of the research:

- maximising the energy delivered;
- reducing undue[1] occupancy of the charging points, i.e. the time exceeding the maximum allowed charging time or when the vehicle reaches full charge.

Table 2 presents an overview of the key results obtained from the static supply modality round. This includes data on the total number of charging sessions per week, the total energy delivered during charging sessions, and the charging sessions' duration throughout each experimentation week.

[1] The term "*undue*" used in the report is defined as "excessive or unwarranted; unjust, improper, or illegal" according to the Collins dictionary. In the context of the PRISM project, the undue occupancy of the parking spot refers to occupying the spot either beyond the maximum allowed time or after the EV has reached full charge.

Table 1. Main features of experimentation round #1 (Static supply modality).

EXPERIMENTATION ROUND #1: STATIC SUPPLY MODALITY	
Research question(s)	- To test user behaviour in relation to different supply conditions; - To test the effectiveness of different communication systems.
Beginning/End dates	12/09/2022 – 18/11/2022
Number of weeks of experimentation	9 (3 x3)
Supply conditions	Weeks 1-3 (block 1) / weeks 4-6 (block 2) / weeks 7-9 (block 3): - Week 1 / 4 / 7 → 6 A for max 4 hours; - Week 2 / 5 / 8 → 12 A for max 2 hours; - Week 3 / 6 / 9 → 24 A for max 1 hour.
Additional information (e.g. type of communication, visuals, etc.)	The round was structured into three 3-week blocks, with the supply conditions being modified weekly and repeated every three weeks. Different communication resources were employed to encourage users to make more effective use of the charging stations, with increasingly explicit messaging being delivered. This included leveraging the JRC "Connected" intranet and visual signage.
Types of statistics/ computations performed	Key Performance indicators taken in into account included: - Maximising the energy delivered by the 9 AC-charge-points; - Minimising undue occupancy of the parking spots.

Source: JRC DES-Lab, 2023

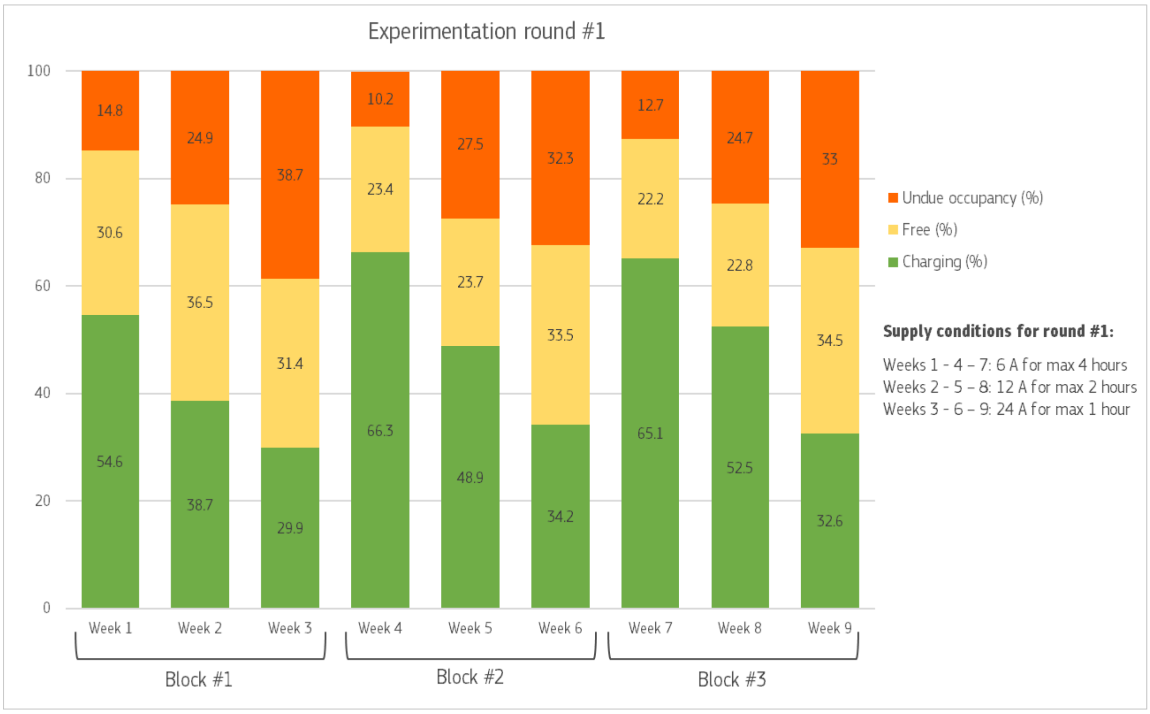
Table 2. Experimentation round #1 - Weekly breakdown across the three research blocks.

	ENERGY DELIVERED [kWh]	**TOTAL TIME [hh:mm:ss]**	**NR. SESSIONS [-]**
WEEK 1	414.5	332:38:28	112
WEEK 2	479.8	200:38:11	123
WEEK 3	679.2	181:14:22	179
SUBTOTAL	***1573.5***	***714:31:01***	***414***
WEEK 4	471.6	341:45:03	106
WEEK 5	652.6	267:37:04	147
WEEK 6	804.7	188:29:59	205
SUBTOTAL	***1928.9***	***797:52:06***	***458***
WEEK 7	456.9	349:30:00	104
WEEK 8	697.2	288:12:09	158
WEEK 9	779	184:47:29	196
SUBTOTAL	***1933.1***	***822:29:38***	***458***

Source: JRC DES-Lab, 2023

Figure 4 offers a detailed breakdown of the charge points' occupancy for each week of the three research blocks.

Figure 4. Experimentation round #1 - Type of occupancy of charging points (% time) – All three research blocks of three weeks each.



Source: JRC DES-Lab, 2023

3.1.1 Main findings

The static supply modality experimentation (round #1) produced the following results:

- the total energy delivered consistently increased over the entire 9-week experimentation period, reaching a peak of nearly 2000 kWh per week (see Table 2);
- the total effective charging time also showed an upward trend, reaching a peak of 822 hours during the final 3-week block, indicating an overall improvement in user behaviour throughout the experimentation period;
- however, a reduction in the maximum allowable time for each charging session appeared to be linked to a higher incidence of prolonged undue occupancy of the charging points (see Figure 4). A potential reason for this issue is that some employees with EV in charging mode may struggle to break their half-day work routine when asked to charge for less than 4 hours.

Additional details are available in [3].

3.2 Summary of experimentation round #2 (November 2022 – February 2023)

The second round of the experimentation ran for 9 weeks, from 21 November 2022 until 24 February 2023. It entailed a **dynamic set-up**, fully leveraging the smart-charging features of the PRISM AC-charge-poles.

During this phase, the PRISM chargers delivered a maximum power that was virtually aligned with the PV production by the solar panels installed on the roof of the parking area in the JRC site Ispra internal road “Via Grecia”.

The actual electric power provided by PRISMs to JRC staff’s EVs is electricity originating from the JRC site’s grid. This energy primarily comes from the JRC’s co-generation plant, with additional electricity sourced from the Italian grid, and on-site PV installations.

The research aimed at maximising the use of PV-generated energy for charging EVs, as well as at analysing user behaviour and determine the most suitable maximum charging time for JRC staff when *declaredly using the charging stations during PV production*.

Throughout this round, EVs were supplied with varying energy amounts based on PV production, with a minimum 6 A electric current guaranteed. Users were encouraged to respect a maximum charging time and to restrict their charging usage to once daily, in order to accommodate more users and optimise infrastructure utilisation.

The PV-optimised experimentation round was divided into three blocks, each lasting three weeks, during which the maximum allowed charging time was adjusted.

A summary of the round’s features is outlined in Table 3.

Three KPIs were considered while assessing users’ behaviour, i.e.:

- Maximisation of the energy delivered;
- Reduction of undue occupancy of the charging points;
- Maximisation of self-consumption (i.e., using the energy produced by PVs as much as possible).

At the conclusion of each experimentation block, results were analysed and then shared with users through posts on the former JRC intranet (“Connected”).

A summary of the main outcomes from this session is provided below.

Table 3. Main features of experimentation session #2 (Dynamic set-up).

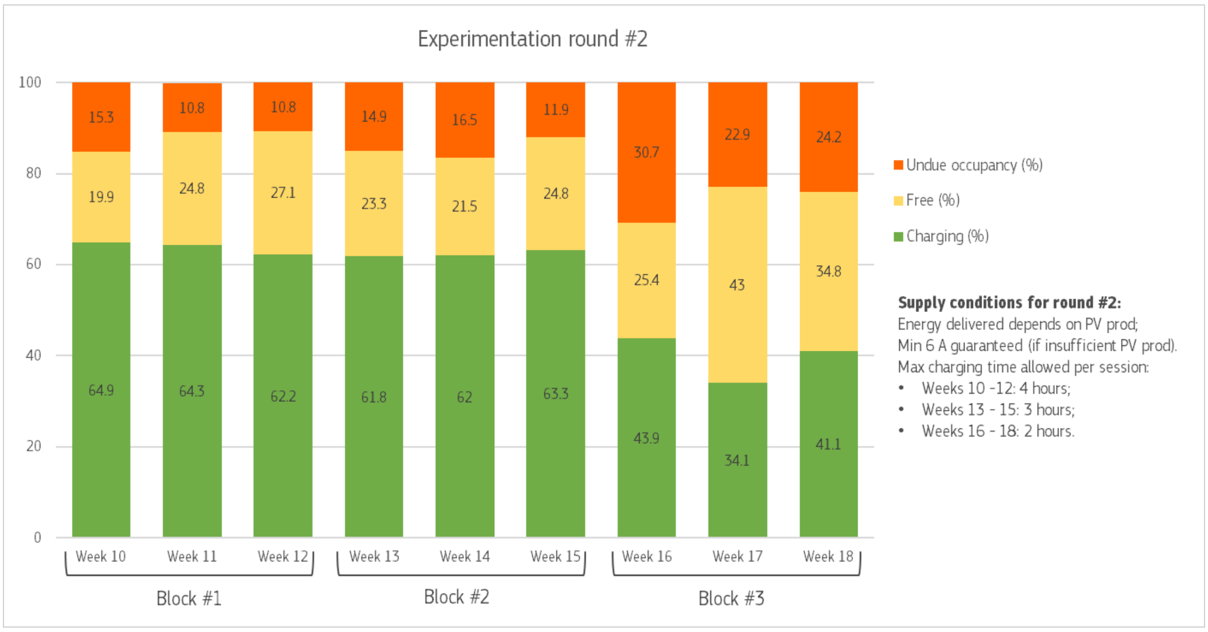
EXPERIMENTATION ROUND #2: DYNAMIC SET-UP	
Research question(s)	Can we charge our EVs using the energy produced by the photovoltaic panels installed in the JRC internal road “via Grecia”?
Beginning/End dates	21/11/2022 – 24/02/2023
Number of weeks of experimentation	9 (3x3)
Supply conditions	- Energy delivered depends on PV production; - Minimum 6 A of electric current guaranteed (if insufficient PV production). - Maximum charging time allowed per session: • Weeks 10-12: 4 hours; • Weeks 13-15: 3 hours; • Weeks 16-18: 2 hours.
Additional information (e.g. type of communication, visuals, etc.)	Varying communication strategy to encourage users to charge their vehicles during peak energy production from PVs.

Types of statistics/computations performed	KPIs considered: - Maximisation of the energy delivered; - Reduction of undue occupancy of the charging points; - Maximisation of self-consumption (i.e. using the energy produced by PVs to charge the EVs as much as possible).

Source: JRC DES-Lab, 2023

Figure 5 provides details on the occupancy of the charging points, during each week of the research blocks.

Figure 5. Experimentation round #2 - Type of occupancy of charging points (% time) – All blocks.



Source: JRC DES-Lab, 2023

For each 3-week block, table 4 displays the total electricity produced by the PV panels across the parking area in the internal JRC-site's road "via Grecia", the total electricity supplied by PRISM chargers, and the total electricity produced by PVs that was directly used for EV charging (i.e. self-consumption).

Table 4. Experimentation round #2 - PV production, charging stations' consumption and rate of self-consumption for each 3-week block.

	ELECTRICITY PRODUCED BY PVS [kWh]	PRISM CHARGERS SUPPLY [kWh]	SELF-CONSUMPTION (ELECTRICITY PRODUCED BY PVS INSTANTANEOUSLY USED) [kWh]	% SELF-CONSUMPTION OVER PRISM SUPPLY
BLOCK 1 (W10-W12)	1883	1809	1112	61.5
BLOCK 2 (W13-W15)	1846	1730	1152	66.6
BLOCK 3 (W16-W18)	4147	2236	1998	89.4

Source: JRC DES-Lab, 2023

3.2.1 Main findings

- During the first 3-week block (4-hour max session duration), data show that the PRISM chargers were used less during the central hours of the day, when the power available to EVs tends to be higher. This may be explained by the fact that the 4-hour charging session ends on average around noon, and that this coincides with lunch break, when EV owners pick up their vehicles.

- During the second 3-week block, a significant peak in excessive slot occupancy was observed around 11:00 am, coinciding with the 3-hour maximum session duration. This observation revealed the challenges JRC staff encountered in unplugging their EVs during the mid-morning. Similar challenges were also observed in the afternoon, albeit to a lesser extent. This trend could potentially be linked to the highest concentration of physical and virtual meetings around 11 am.

- Additionally, during this second 3-week experimentation block, undue occupancy persisted around peak daytime (when favourable weather conditions yield increased PV production). A possible interpretation of this is that users overlook their responsibility to vacate the charging slots around lunchtime, thereby hindering other colleagues from maximising their charging sessions using virtual renewable energy.

- During the third 3-week block with a 2-hour max session duration, there was a significant overall increase in the duration of undue occupancy compared to the previous 3-week blocks with 4-hour and 3-hour sessions, as shown in Figure 4. This pattern was also observed during the first 9-week experimentation round (#1), indicating a clear correlation between the reduction in the maximum allowed charging time per session (2 hours) and a significantly higher rate of undue occupancy of the charging points. This confirms a similar observation in the experimentation round #1 (see section 3.1.1): where the maximum allowed charging time should typically fit half a work day, in order to not disturb staff from their normal working routine.

- Despite the higher amount of virtually self-consumed electricity in the last 3-week block (Table 4), a significant decrease in effective charging during PV peak production is observable, again indicating the increased difficulties for colleagues to pick up their cars when their sessions start and end in the morning.

To sum up:

- At the peak of electricity production from PV panels, a decrease in consumption is detected, resulting in underutilisation of the renewable energy available to the EVs. This is mainly due to users leaving their cars plugged in beyond the maximum time allowed during the central hours of the day, which coincide with the highest PV production.

- The research indicates a concerning trend, with specific statistics showing a 58% peak in undue slot occupancy during the hours of maximum PV production. It is evident that the rules for fair use of the PRISM chargers were not respected. In particular, data indicate that the shorter the maximum allowed charging time, the higher the percentage of undue occupancy. In addition, multiple charging sessions from the same EV owners in one day were also observed.

- Overall, there is need for better adherence to the rules for fair use of PRISM chargers, as well as greater awareness of the optimal timing for charging during the central hours of the day in order to maximise the use of renewable energy for electric vehicles.

Additional details are available in [3].

3.3 Experimentation round #3 (February – April 2023)

Experimentation round #2 highlighted two main behavioural obstacles affecting the optimal use of the PRISM charging points:

- A tendency to charge EVs multiple times and beyond the allowed time, thereby generating undue occupancy limiting access for other users;
- A robust pattern of users charging in the morning or afternoon, but not at lunchtime, missing the peak charging power from solar production.

These findings highlighted the need for improved user coordination and presented an opportunity for collaboration between DES-Lab and the Competence Centre on Behavioural Insights (CCBI), a team within the EU Policy Lab (JRC, Unit S1). The CCBI team recognised an opportunity to improve users' coordination with a refined communication strategy using charge-field signage, e-mails, and posts on the JRC Intranet "Connected". Testing this strategy's effectiveness was the main objective of the experimentation.

The experiment spanned six weeks, from 27 February until 21 April 2023, with research conditions changing every three weeks, adjusting the maximum time allowed for each charging session.

The experimentation round aimed to encourage users to:

- Comply with the rules of the PRISM charging stations set by DES-Lab;
- Shift charging sessions when the solar energy powering the stations is at its peak;
- Reduce undue occupancy by leaving the station at the end of the charging session.

Achieving these goals was challenging because using the charging stations during lunchtime, when solar power is at its peak, could also promote another healthy activity, such as walking to lunch while leaving the vehicle to charge.

3.3.1 Behaviourally informed communication

The CCBI proposed to elaborate behaviourally informed communication strategies to inform users about the following facts:

- Show the distribution of undue occupancy during the day, thereby improving coordination by giving users more information on the day-to-day use of the charging stations;
- Illustrate the peak hours of electricity production from PV panels during the day.

The main hypothesis was that providing this information would reduce undue occupancy of the charging spots and increase occupancy during peak hours.

To evaluate the effectiveness of the enhanced communication strategy, CCBI performed a pre-post analysis using DES-Lab data usage to examine changes in consumption before and after the communication intervention. This analysis compared the research conditions during the first six weeks of experimentation rounds #2 and #3, as outlined in Section 3.3. By maintaining the same supply conditions as in rounds #2 and #3, the study was able to isolate the effects of communication framing on user behaviour (specifically, undue occupancy) and the supply of PV-produced electricity (in kWh).

However, while pre-post analysis can assess an intervention's effectiveness, it has limitations for drawing causal inferences. Other factors influencing the outcome may change over time, acting as confounding variables.

A summary of the main features of the experimentation round is given in Table 5.

Table 5. Main features of experimentation round #3.

EXPERIMENTATION ROUND #3: FIRST EXPERIMENTATION WITH CCBI	
Research question(s)	Can we reduce unnecessary occupancy of EVs at the charging stations through an ad-hoc communication strategy?
Beginning/End dates	27/02/2023 – 17/03/2023 20/03/2023 – 21/04/2023 (excluding period from 03/04 to 14/04)
Number of weeks of experimentation	3 + 3
Supply conditions	- Charging time (W19 – W21): maximum 4 hours; - Charging time (W22 – W24): maximum 3 hours; - 1 charging session per day per person; - Supply from PV panels; - 6 Amps of current guaranteed [1.4 kW] (if insufficient production from PVs).
Other conditions (credits, RFID, penalties, etc.)	---
Additional information (e.g. type of communication, visuals, etc.)	Communication – increased use of impacting visuals. Explicit invitation to charge cars during lunchtime to exploit the energy peak produced by PVs.
Types of statistics/computations performed	Pre-post analysis to investigate differences in consumption before and after the communication intervention.

Source: JRC DES-Lab, 2023

3.3.2 Experimentation with the refined communication strategy

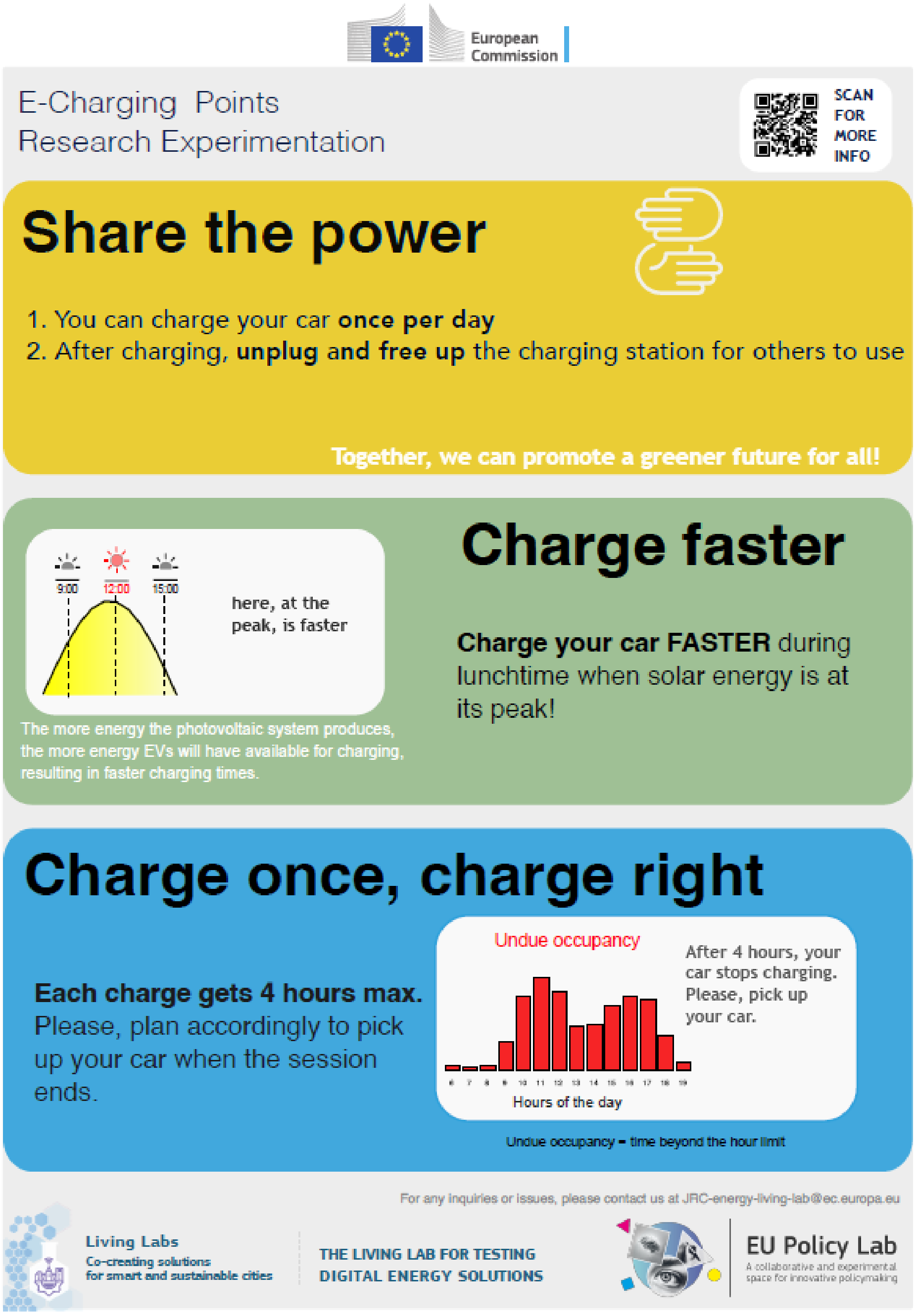
New charge-field signage and reframed messages were developed.

The experimentation commenced on 27 February 2023. On February 24th, users were e-mailed about the new experimental use conditions and installed signage (see Figure 6) at the charge-field, both promoting a responsible use (“*share the power*”), providing information on the advantages of charging during solar peak hours (“*charge faster*”). The signage also showed the distribution of undue occupancy during the day, aimed at fostering better coordination (“*charge once, charge right*”). The same information was also posted on the JRC Intranet “Connected”.

The signage was placed at the charge-field for maximum visibility. One large poster in A2 format was placed on the cabinet near the screen that EV owners use to start their charging session. Smaller posters in A4 format were positioned on the poles of each charging station (Figures 7 and 8). Figures 9 and 10 show the text e-mailed and posted on Connected for the first 3-week experimentation.

Similar reminders were e-mailed and posted on the JRC Intranet "Connected" before the beginning of the second 3-week experimentation block. Both e-mail and post were sent and published on 17 March, three days before the actual experimentation block (20 March 2023).

Figure 6. New signage for the PRISM charge-field designed by the EU Policy Lab.



Source: JRC DES-Lab, 2023

Figure 7. Signage positioned on the cabinet.

Source: JRC DES-Lab, 2023

Figure 8. Signage positioned on the poles of each charging station.

Source: JRC DES-Lab, 2023

Figure 9. E-mail sent to PRISM users and framed by the EU Policy Lab.

Dear Colleagues,

Get ready for a fresh start! Next Monday, 27th of February, we're embarking on a new experimental period and we're doing it as a **team** once again!

The goal is unchanged, that is to test user's behaviour and to assess energy demand and response against photovoltaic production.

As always, let's make sure to **share the power with our colleagues:**

- ☺ You can **charge your car only once per day.**
- ☺ **After charging, unplug and free up the charging station for others to use**
- ☺ Each charging session takes **4 hours maximum**

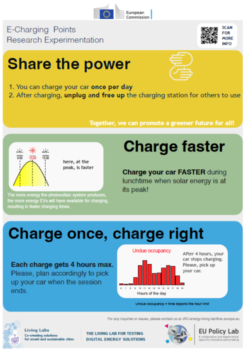
Such experimental conditions will run over the next three weeks, namely:

27 February – 3 March;

6 March – 10 March;

13 March – 17 March

Do you want to **charge your car faster? Lunchtime** is the perfect time! Take advantage of solar energy when the sun is shining the brightest! A **minimum current of 6 Amps** (1,4 kW) is guaranteed but solar production **can get up to 50 kW** on the sunniest days!



The living lab is delighted to continue its experimentation phase with you!

For any inquiries or issues, please contact us at JRC-energy-living-lab@ec.europa.eu.

Kind Regards,

The Living Lab for testing Digital Energy Solutions, Directorate C

The Competence Centre for Behavioural Insights, Directorate S

Source: JRC DES-Lab, 2023

Figure 10. Post on Connected prepared by the EU Policy Lab for the second three-week experimentation block.

Source: JRC DES-Lab, 2023

3.3.3 Main findings

The experimental results provided no significant behavioural changes post intervention, likely due to statistical limitations and other factors. This result does not dismiss the possibility that the information prompted a behavioural change. However, it indicates that if there was an effect, it was likely small, and such small effects are not detectable with our limited sample size.

Another potential limiting factor that may have reduced effectiveness is the extent to which EV owners paid attention to the signal and information. Although direct information on this is lacking, it seems improbable given that the signage was strategically placed to capture the attention of EV users, and all users received multiple e-mails.

Therefore, this experiment suggests that relying solely on information is insufficient to drive significant behavioural changes in this context.

3.4 Experimentation round #4 (May 2023 – July 2023)

In an effort to improve the overall use of the charge-field, decrease the duration of undue occupancy, and enhance user experience, DES-Lab decided to test and subsequently implement an RFID (Radio Frequency Identification) system. This new system enabled JRC staff to use their badges to access any of the free charging stations and draw power using a token-driven supply modality.

A two-week trial period on the new RFID system was carried out prior to its official launch on 15 May 2023. The experimentation round lasted for ten weeks, and concluded on 21 July 2023.

3.4.1 Sign-up procedure

To use the charge-field under the new supply modality, users were asked to register and provide their consent for the processing of the data collected for the research project. All necessary information for registration and the privacy statement can be found at https://energylab.jrc.cec.eu.int/prism/info.php or accessed directly from the PRISM dashboard (https://energylab.jrc.cec.eu.int/prism/).

The sign-up procedure is outlined in Figure 12. Registrations were available starting in April 2023. From April until December 2023, a total of 125 JRC colleagues had signed up to use the charge-field (Figure 11).

3.4.2 Data processed

Upon registering for the EV charge-field, users consented to the processing of the following data:

– corporate email address (for notifications on EV charging sessions and other user-related information);

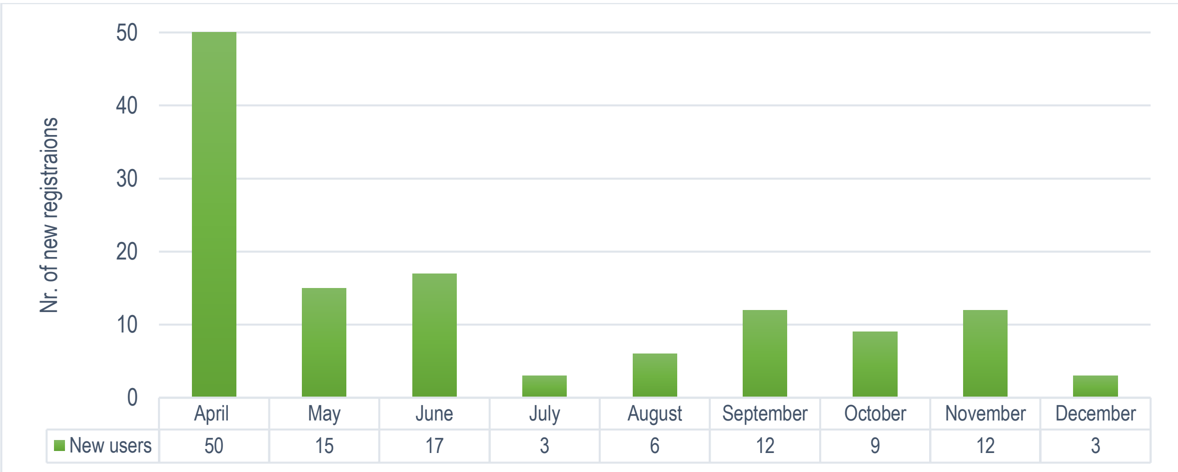
– brand and model of e-vehicle (to conduct tests on how the e-vehicles respond to given supplied power);

– distance "home – JRC" (useful to design fair charging policies), expressed approximately in kilometre ranges;

– charging session details (start time, power supplied, stop time).

All data related to charging sessions are aggregated prior to any publication or statistical computation.

Figure 11. Number of new registrations to use the DES-Lab charge-field (April – December 2023).



Source: JRC DES-Lab, 2024

Figure 12. Sign-up procedure.

EV Charging Stations (JRC Ispra) Dashboard

To register for the EV charging system, follow these steps:

1. Head to the totem located in the parking lot on via Grecia, adjacent to the Solar House. Swipe your badge on the cabinet above the totem. Afterwards, follow the on-screen instructions and complete the registration form.
2. To finalise your registration, check your corporate e-mail. You will receive a message prompting you to provide consent for the processing of your data within the scope of this research project.
3. Once registered, you will be able to charge your car. Your badge will be credited with a specific number of credits associated with your RFID code.
4. Credits are utilised when charging your vehicle and are also deducted if you exceed the maximum parking time allowed or if your car reaches a full charge.
5. Given that this is a JRC research project, the credit system will undergo periodic changes. Notifications regarding the modifications will be sent to your corporate e-mail.

You can monitor the charging column status through the NET1 web page: https://energylab.jrc.cec.eu.int/prism/.

Keep in mind that your JRC badge is linked to a single vehicle. If you plan to use the charging system with multiple vehicles, submit a request for an additional ad-hoc badge to JRC-energy-living-lab@ec.europa.eu.

These steps ensure a smooth registration process and provide essential information for utilising the EV charging system in compliance with the JRC research project requirements.

Source: JRC DES-Lab, 2023

3.4.3 Credit / penalty system

Previous experimentation rounds (Sections 3.2 and 3.3) highlighted a significant issue with prolonged occupancy of the charging points beyond the maximum allowed time for a charging session, as well as violations of the one-time-a-day charging session rule.

Therefore, to incentivise positive behaviours in chargers' use and to distribute power more equitably among users, a non-monetary credit/penalty system was introduced.

At the start of each two-week experimentation block, users' badges were loaded with an allotted amount of 100 digital "credit-tokens", called "credits" for short, to be spent for EV charging, and subject to the following rules:

- each kWh of electricity delivered corresponded to 1 credit, indicating that each user could draw a maximum of 100 kWh in two weeks;
- every five minutes of undue occupancy led to the deduction of one credit (penalty);
- users were allowed to charge their vehicles for maximum three hours per session.

A summary of the experimentation round's features is provided in Table 6.

Table 6. Main features of experimentation round #4 (RFID and credit/penalty system)

EXPERIMENTATION ROUND #4: RFID AND CREDIT SYSTEM	
Research question(s) / objective(s)	- How can we further decrease undue occupancy? - How can we increase turnover among users, allowing maximum one single charge per day?
Beginning/End dates	15/05/2023 – 21/07/2023
Number of weeks of experimentation	10
Supply conditions	- Charging session duration: maximum 3 hours; - Supply from PV panels; - Minimum 6 Amps of current guaranteed in case of insufficient supply from PVs;
Other conditions (credits, RFID, penalties, etc.)	- Introduction of authentication through the RFID system. - Introduction of credits and penalties: 1 credit spent for each kWh of energy, and 1 credit (as penalty) for every 5 minutes of undue occupancy. - Each user was granted 100 credits every two weeks.
Additional information (e.g. type of communication, visuals, etc.)	- Information mostly by sending e-mails to registered users.
Types of statistics/computations performed	Type of occupancy, total energy delivered, number of charging sessions, use of credits for EV charging as well as for penalties, PV production / self-consumption

Source: JRC DES-Lab, 2023

3.4.4 Communication strategy

DES-Lab prepared new communications to staff using both signage at the charge-field (to include the new registration procedure) and e-mails to registered users.

The use of JRC's "Connected" intranet-webpage was very limited, for two main reasons:

- A mailing list of registered users was available, thanks to the new sign-up procedure;
- The imminent decommissioning of the JRC's "Connected" intranet was already announced at higher level, and for reasons that were unrelated to the DES-Lab project.

3.4.5 Main findings

The figures below display data on the 10-week experimentation round. Some results are provided for experimentation blocks of two weeks each, matching the time given to users for spending their 100 credits before reset.

3.4.5.1 Charging sessions and supply to EVs

Table 7 and Figures 13-14 present a summary of the main data collected on the charging sessions over the 10-week period, including the number of charging sessions per week and the total electricity delivered per week.

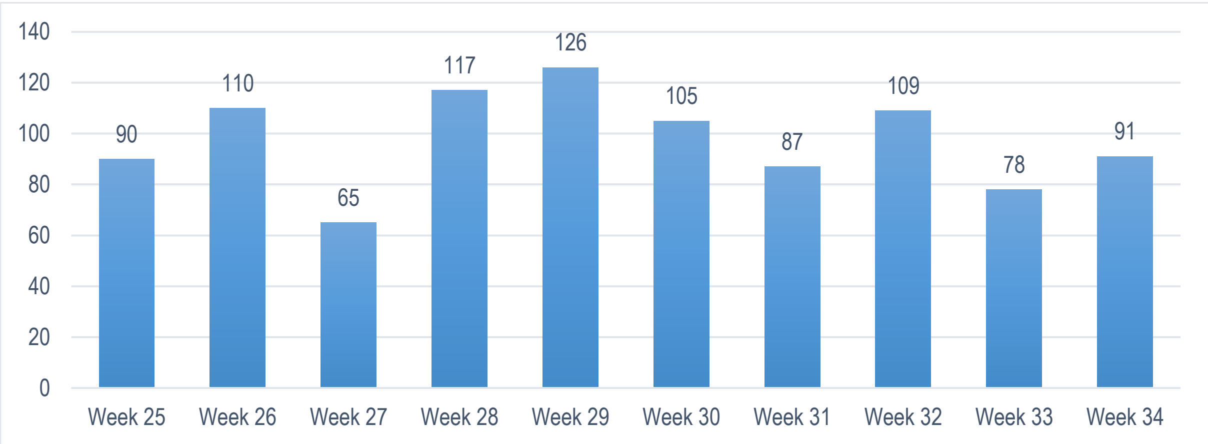
Table 7. Charging sessions data for the experimentation round #4 (15 May – 21 July 2023).

	DATES	TOT NR. SESSIONS/WEEK	TOTAL ELECTRICITY DELIVERED / WEEK (kWh)
WEEK 25	15/05-19/05*	90	593
WEEK 26	22/05-26/05	110	832
WEEK 27	29/05-01/06*	65	600
WEEK 28	05/06-09/06	117	995
WEEK 29	12/06-16/06	126	806
WEEK 30	19/06-23/06	105	863
WEEK 31	26/06-30/06	87	686
WEEK 32	03/07-07/07	109	876
WEEK 33	10/07-14/07	78	662
WEEK 34	17/07-21/07	91	807
TOTAL		**978**	**7720**

*With the exception of the following dates: 18/05, 29/05 and 02/06, when the JRC was closed.

Source: JRC DES-Lab, 2024

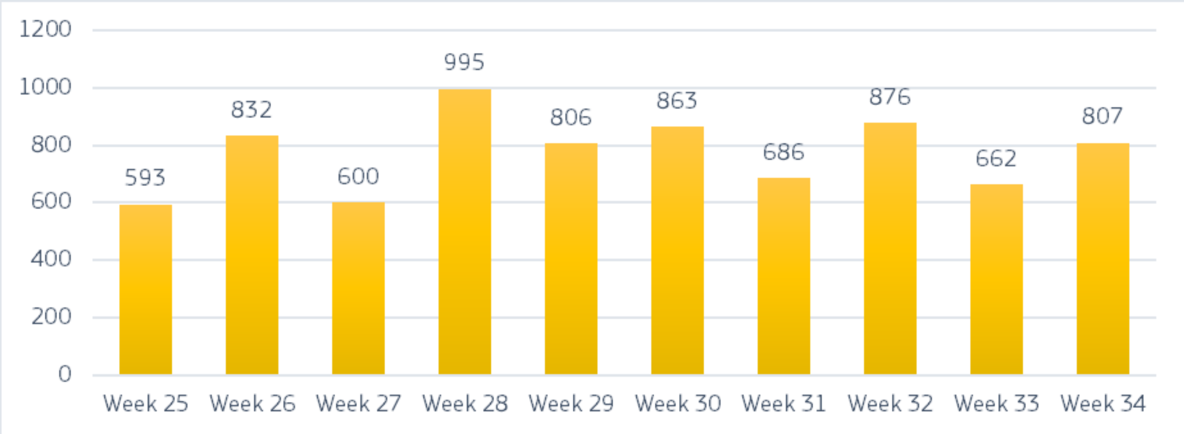
Figure 13. Experimentation round #4 - Number of charging sessions per week.



Source: JRC DES-Lab, 2024

As shown in Figures 13 and 14, the weeks with the highest number of charging sessions are weeks 28 and 29 (early to mid-June), with week 28 also representing the period during which the highest amount of electricity was delivered. On the contrary, it appears that week 27 had the lowest number of sessions and the least amount of electricity supplied. This is attributed to the fact that two days of that week were JRC Ispra holidays.

Figure 14. Experimentation round #4 - Total electricity delivered for charging sessions per week [kWh].

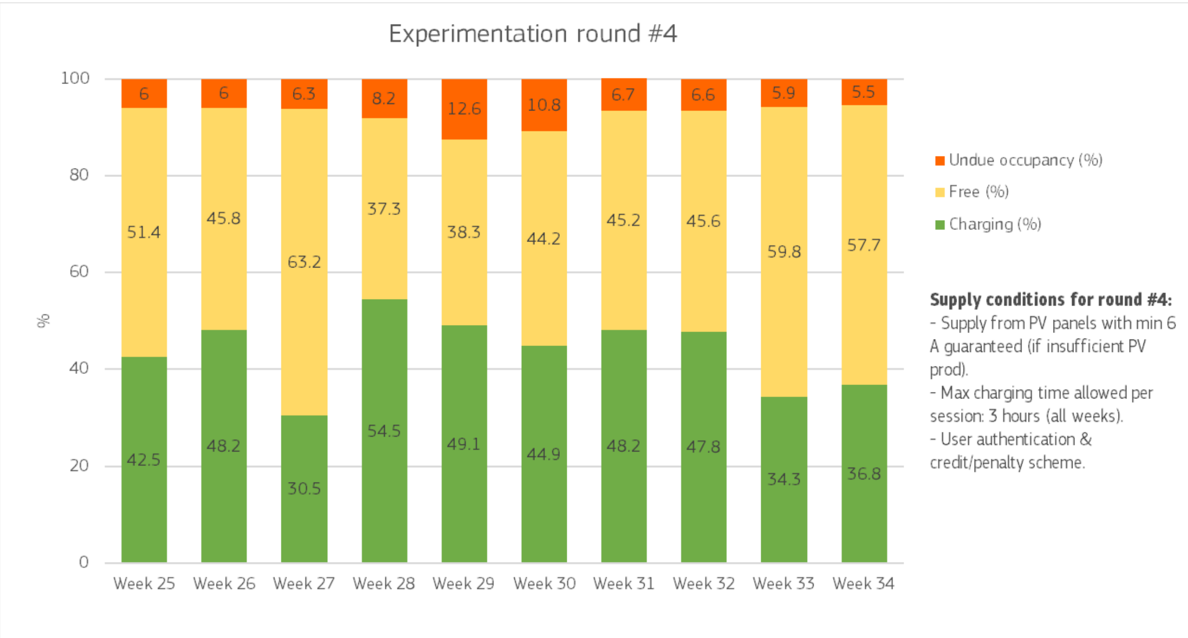


Source: JRC DES-Lab, 2024

3.4.5.2 Type of occupancy and penalties

As shown in Figure 15, the month of June is characterised by a higher level of charge-field occupancy, whereas the weeks in July were the least used. This trend is linked to the reduced number of employees on site due to summer holidays. Again, week 27 is associated with the lowest level of occupancy for EV charging.

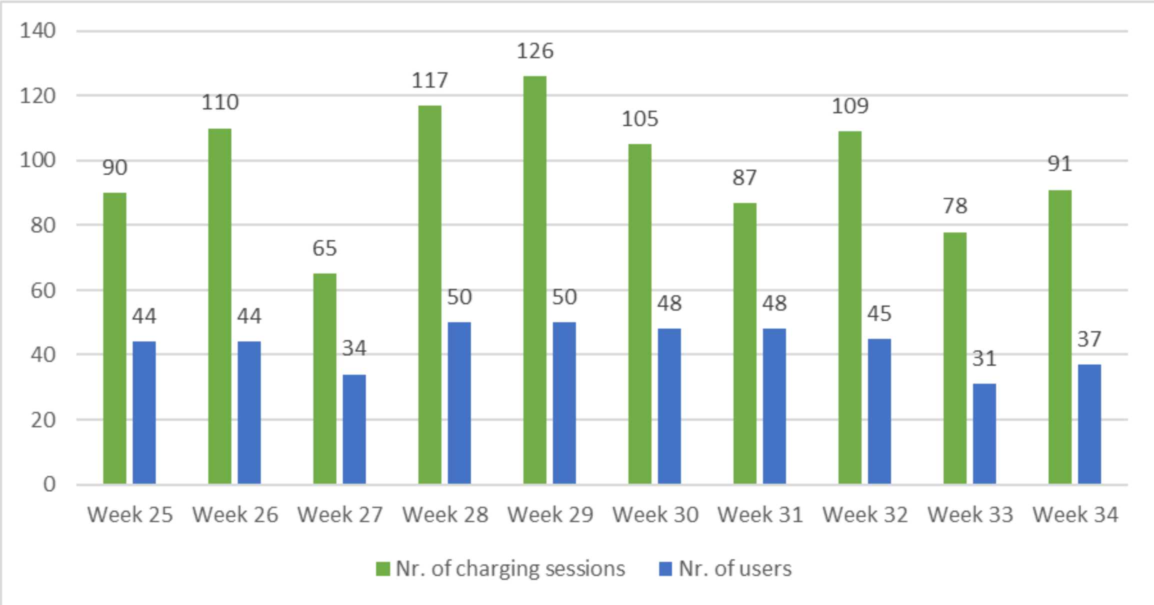
Figure 15. Experimentation round #4 - Occupancy [in %] of the charge-field per week.



Source: JRC DES-Lab, 2024

The highest levels of undue occupancy are once again observed during weeks 29 and 30 (around mid-June), although these percentages appear to be lower compared to weeks 22-24 of the previous experimentation session (Section 3.3). This decrease may also be due to a diminished charge-field usage during the summer holidays.

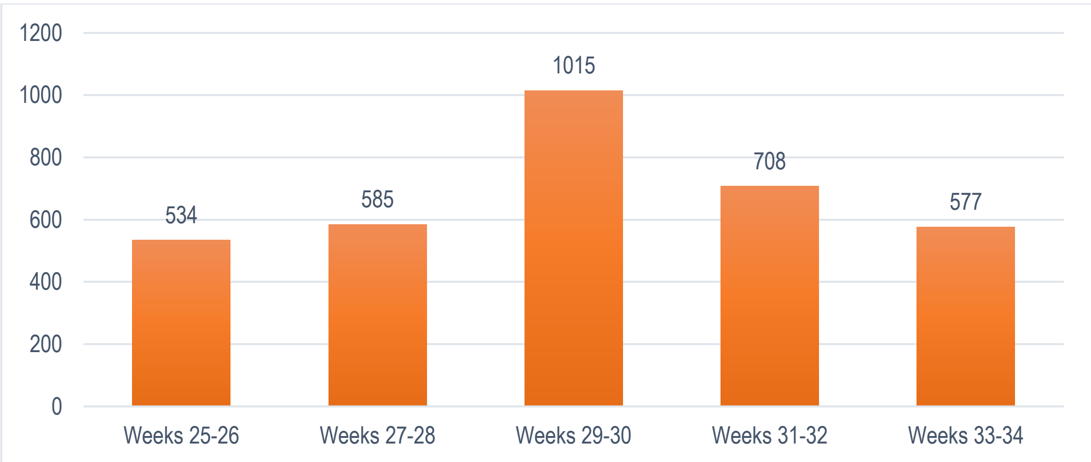
Figure 16. Experimentation round #4 - Number of users and charging sessions per week.



Source: JRC DES-Lab, 2024

Figure 17 shows the total number of penalties given to users for undue occupancy of the charging points for each two-week period of the experimentation session. The highest number of penalties was given during weeks 29 and 30, which are also characterised by the highest number of charging sessions performed (Figure 16), as well as those associated with the highest proportion of undue occupancy, as depicted in Figure 15.

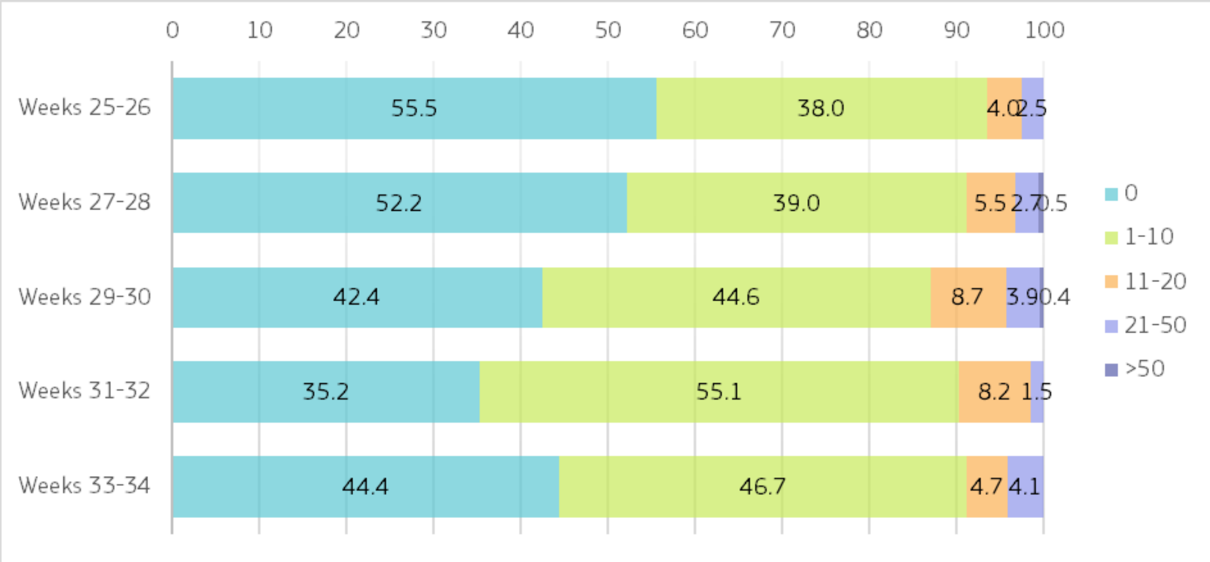
Figure 17. Experimentation round #4 - Total number of penalties inflicted for each two-week period.



Source: JRC DES-Lab, 2024

Figure 18 shows that no more than 10 penalties were given during the two-week periods for the vast majority of the charging sessions. More than half of the charging sessions during weeks 25-26 and 27-28 received no penalties at all. This trend changes starting from weeks 29-30, when the highest percentage of sessions received an amount of penalties ranging from 1 to 10.

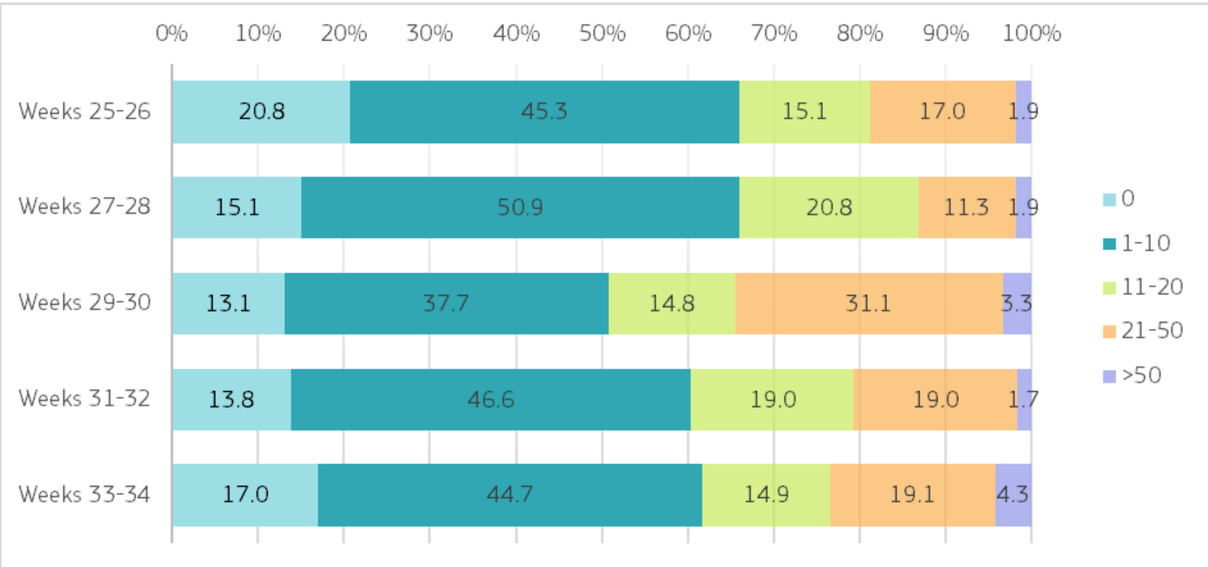
Figure 18. Experimentation round #4 - Percentage of sessions that received a number of penalties (within a range).



Source: JRC DES-Lab, 2024

Figure 19 reveals that the majority of users were given a number of penalties ranging from 1 to 10 during all two-week periods. However, a significant proportion of users also received a high number of penalties ranging from 21 to 50, especially during weeks 29-30. As mentioned earlier, weeks 29 and 30 are those associated with both the highest number of charging sessions and the highest proportion of undue occupancy. These two elements indicate that it was more likely for staff to receive significant amounts of penalties compared to other two-week periods during round #4.

Figure 19. Experimentation round #4 - Percentage of users who received a total number of penalties falling within a specific range.

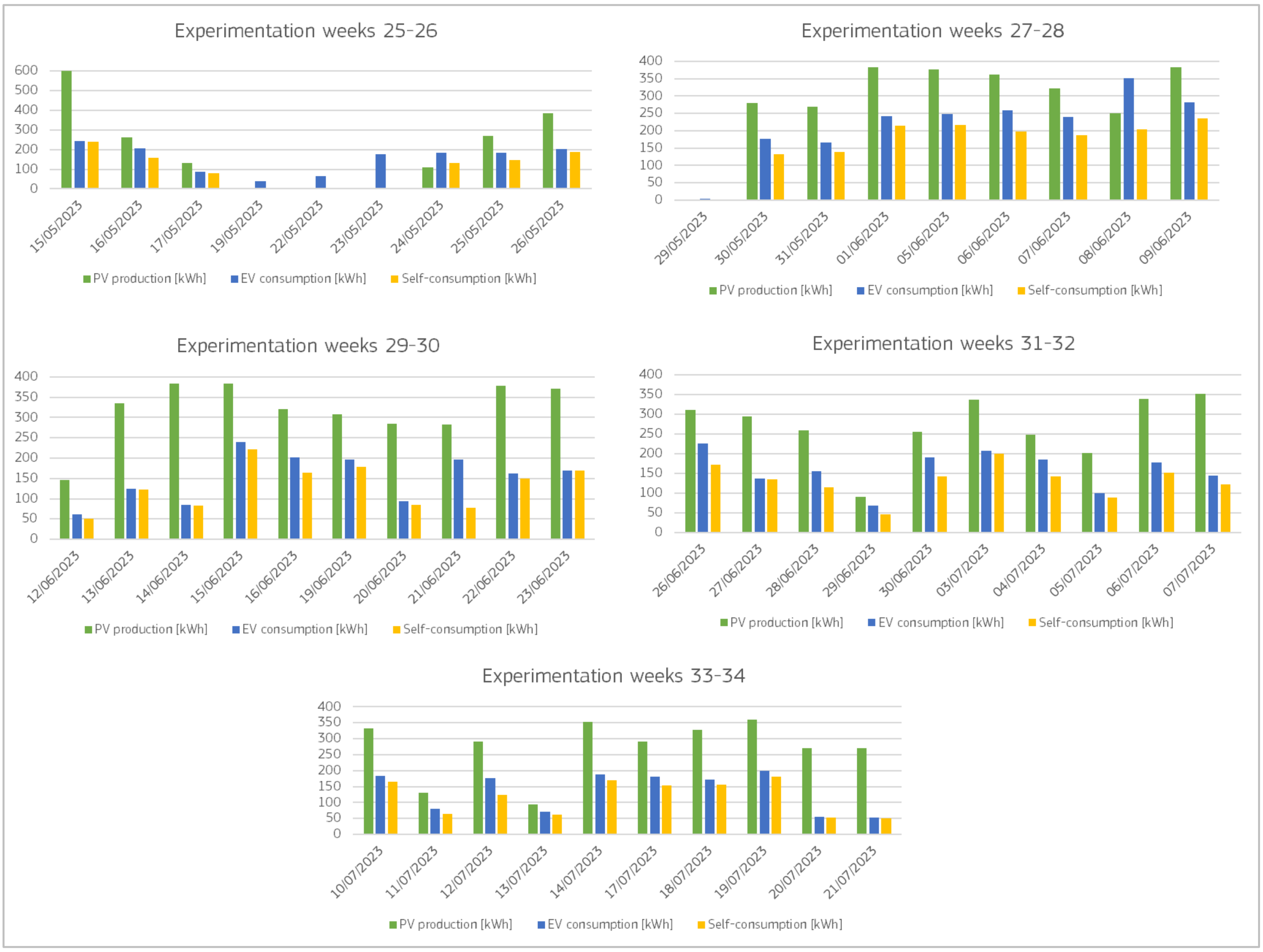


Source: JRC DES-Lab, 2024

3.4.5.3 Electricity produced by PV panels and supply to EVs

Figure 20 shows the daily production of electricity from PVs (in green), the amount of electricity supplied during the charging sessions (in blue), and the portion of PV-produced electricity that was instantaneously used for charging (in yellow).

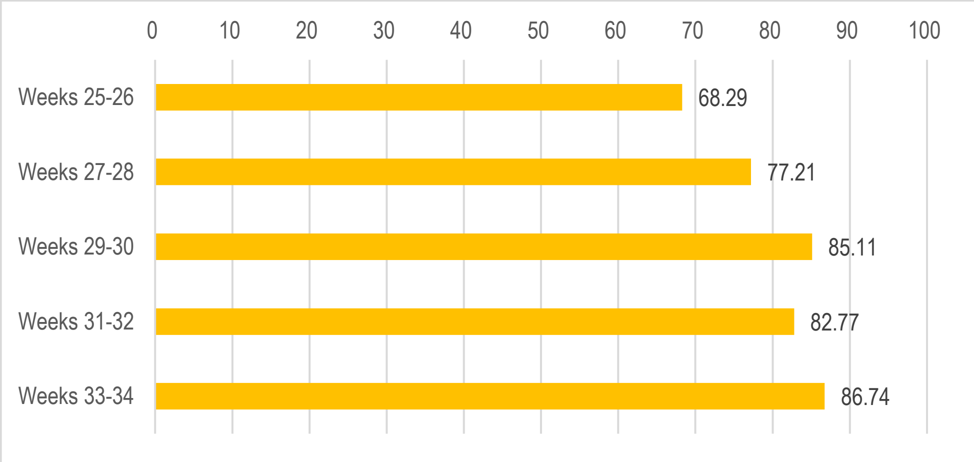
Figure 20. Experimentation round #4 - PV production, EV supply and self-consumption data.



Source: JRC DES-Lab, 2024

As illustrated in Figure 21, the proportion of solar-generated electricity used for immediate EV charging increased consistently throughout each 2-week period of the experimentation round, indicating a more efficient use of renewable energy. This trend suggests an increased understanding and implementation of the trial conditions as the experiment progressed within round #4.

Figure 21. Experimentation round #4 - Proportion of electricity produced by PVs instantaneously used for EV charging for each 2-week period [in %].



Source: JRC DES-Lab, 2024

To conclude, the results obtained during this experimentation round have shown that the introduction of the RFID system and the use of the new credit/penalty scheme have led to a reduction in undue occupancy of the charging spots and may represent a valuable method to be implemented for future payment of EV charging sessions.

3.5 Experimentation round #5 (September 2023 – December 2023)

The last experimentation round in 2023 was conducted between September and December[2], again in collaboration with the Competence Centre for Behavioural Insights (CCBI).

The purpose of this round was to investigate the behaviours and choices of EV owners in response to various incentive schemes for utilising a workplace charging stations.

Specifically, this study aimed to understand how EV owners at JRC responded to different credit systems, exploring different credit configurations for different subgroups of users. The goal was to gain insights into the elasticity of demand at increasing costs, and ultimately to inform a cost scheme that would promote efficient use of the charging stations for the users.

This experimentation round was divided into two main phases each lasting six weeks, for a total of twelve weeks. The two phases mainly differed in the modalities of the credit-based system implemented, as described later.

Over 120 JRC colleagues participated in this experimentation.

A description of the main research conditions is provided in the following paragraphs, with a summary of the round's main features outlined in Table 8.

[2] No testing or data collection from the PRISM charging sessions was performed during the summer break (i.e. from August until mid-September 2023).

3.5.1 Supply conditions

The aim of the experimentation round was to test how well the credit system could enhance system flexibility and promote responsible consumption when extending charging sessions' limit from three to six hours. More specifically, the maximum charging session time was extended to six hours for all users, and an evaluation of how increasing charging prices affected user behaviour as the session progresses was performed.

Unlike the previous rounds, the electricity supplied during a charging session was no longer dependent on production from PV panels. Instead, a constant 3.5 kW power supply was provided. This choice was made to simplify the incentives for the users.

3.5.2 The new two-tiered credit system

As described in Section 3.4, a credit-based system was introduced by which each registered user could access the charge-field with their own corporate ID badge. Users received 100 credits every two weeks (10 working days). At the end of this period, unused credits reset and the user's balance reverted to 100 credits.

Table 8. Main features of experimentation round #5.

EXPERIMENTATION ROUND #5: RFID AND TWO-TIERED CREDIT SYSTEM (NEW) – WITH CCBI	
Research question(s)	- How do different pricing schemes affect users? - To what degree do the extended session duration and tiered credit approach affect user experience?
Beginning/End dates	19/09/2023 – 15/12/2023
Number of weeks of experimentation	12 (6+6)
Supply conditions	- Session duration: 6 hours; - Constant supply of 3.5 kW (16 A) (with the exception of some hybrid EV-models, that may be able to receive charging only up to a lower power level).
Other conditions (credits, RFID, penalties, etc.)	- Introduction of a two-tiered credit system that affects the cost of the charging session, based on the duration of the session and the credit scheme assigned. - Each user was granted 100 credits every 10 working days (2 weeks); - To assess the impact of different credit schemes on consumption patterns, users are assigned to either a low-, medium-, or high-cost scheme. Schemes are changed every two weeks, so that each user will belong for two weeks to each of the three schemes (low/medium/high). - **During experimentation weeks [W35-W40]:** 1 credit spent for each kWh used during the first 3 hours of the charging session; - Each additional hour beyond the third hour will have a variable cost per kWh depending on the credit scheme assigned to the registered user (see cost scheme #1 in Table 9). - **During experimentation weeks [W41-W46]:** 1 credit spent for each kWh used during the first hour of the charging session; - Each additional hour beyond the first hour will have a variable cost per kWh depending on the credit scheme assigned to the registered user (see cost scheme #2 in Table 9).

	- Penalties: Users will lose one credit every 5 minutes of undue parking occupation.
Additional information (e.g. type of communication, visuals, etc.)	- Information through email to mailing list. - No Connected used for communication purposes.
Types of statistics/computations performed	Regression analysis to estimate the average differences across the treatment groups. The analysis involves a multiple linear regression using as dependent variable the number of sessions and session duration totalled by users in each two-week period against, as covariates, the assigned cost schedule, indicators for the period, and indicators for the individual user.

Source: JRC DES-Lab, 2024

For the purposes of this new experimentation round, a two-tiered credit system was introduced. Users were randomly assigned to either a low-, medium-, or high-cost scheme. Schemes were changed every two weeks, so that each user belonged for two weeks to each of the three schemes (low / medium / high-cost schemes).

Therefore, the credit system varied as follows.

During the first six experimentation weeks (19 September – 27 October) [W35-W40]:

- users were allowed to charge their vehicles for maximum six hours per session;
- for the first three hours of a charging session, each kWh of electricity delivered cost 1 credit;
- for each additional hour beyond the three-hour threshold, the cost per kWh varied depending on the credit scheme assigned to a specific user (see Table 9);
- every five minutes of undue occupancy led to the deduction of one credit (penalty).

During the second six experimentation weeks (30 October – 15 December)[3] [W41-W46]:

- for the first hour of the charging session, each kWh of electricity delivered cost 1 credit;
- for each additional hour beyond the one-hour threshold, the cost per kWh varied depending on the credit scheme assigned to a specific user (see Table 9).
- All the other conditions remained unchanged.

[3] No data collection between 4 and 8 December 2023.

Table 9. Experimentation round #5 - Cost schemes variations during the experimentation weeks.

	COST SCHEME #1 [EXPERIMENTATION WEEKS 35-40]	COST SCHEME #2 [EXPERIMENTATION WEEKS 41-46]
LOW-COST PLAN (GROUP A)	**1.5 credits** per kWh for any consumption that falls within the 4 to 6-hour window	**1.5 credits** per kWh for any consumption that falls within the 2 to 6-hour window.
MEDIUM-COST PLAN (GROUP B)	**2 credits** per kWh for any consumption that falls within the 4 to 6-hour window.	**2 credits** per kWh for any consumption that falls within the 2 to 6-hour window.
HIGH-COST PLAN (GROUP C)	**2.5 credits** per kWh for any consumption that falls within the 4 to 6-hour window.	**2.5 credits** per kWh for any consumption that falls within the 2 to 6-hour window.

Source: JRC DES-Lab, 2024

3.5.3 Main findings

3.5.3.1 Findings from the first six weeks of experimentation (Weeks 35-40)

Figure 22 illustrates the average differences across treatments in the first six weeks of experimentation (weeks 35-40). These differences were estimated from linear regression, which also accounts for the variations that happen on different days.

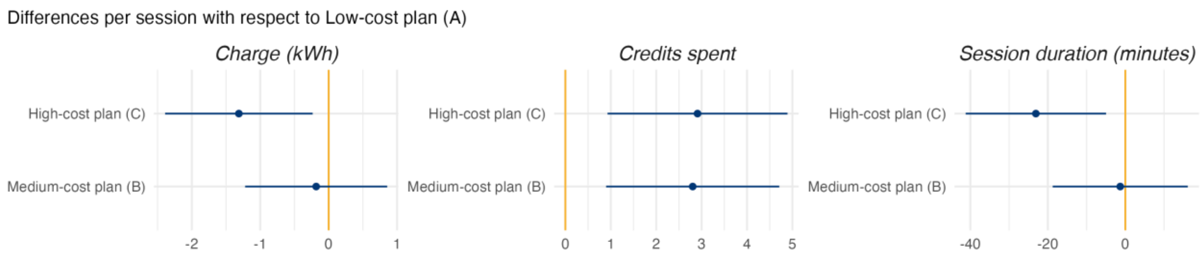
Compared to the low-cost plan, both the medium- and high-cost plans led to a **20% increase in average credits spent**, with users spending 3 more credits per session than the baseline average of 15 credits.

The high-cost plans also led to a significant **reduction of 10% of the session duration**, with 20 fewer minutes off a baseline of 192 minutes average. It also led to a 13% drop in energy consumed per session, with a reduction of 1.3 kWh out of 10 kWh of the baseline average.

The high-cost plan also **produced 20% fewer sessions** than the low-cost one (not shown in the figure), with a statistically significant reduction of 1.5 sessions out of 7 sessions on average.

Overall, these results highlight a strong and significant impact on users' energy consumption in the high-cost plan treatment compared to the low-cost plan.

Figure 22. Experimentation round #5 - Differences across treatment groups in the first six weeks of experimentation (W35-W40).



Source: JRC, 2024

3.5.3.2 *Findings from the second six weeks of experimentation (Weeks 41-46)*

Figure 23 illustrates the distribution of users by the combination of treatment groups experienced over the second six-week experimental session (weeks 41-46). Participants were initially assigned to one group with either low (A), medium (B), or high energy cost (C). Then, every two weeks, they were re-assigned to a different group not experienced before.

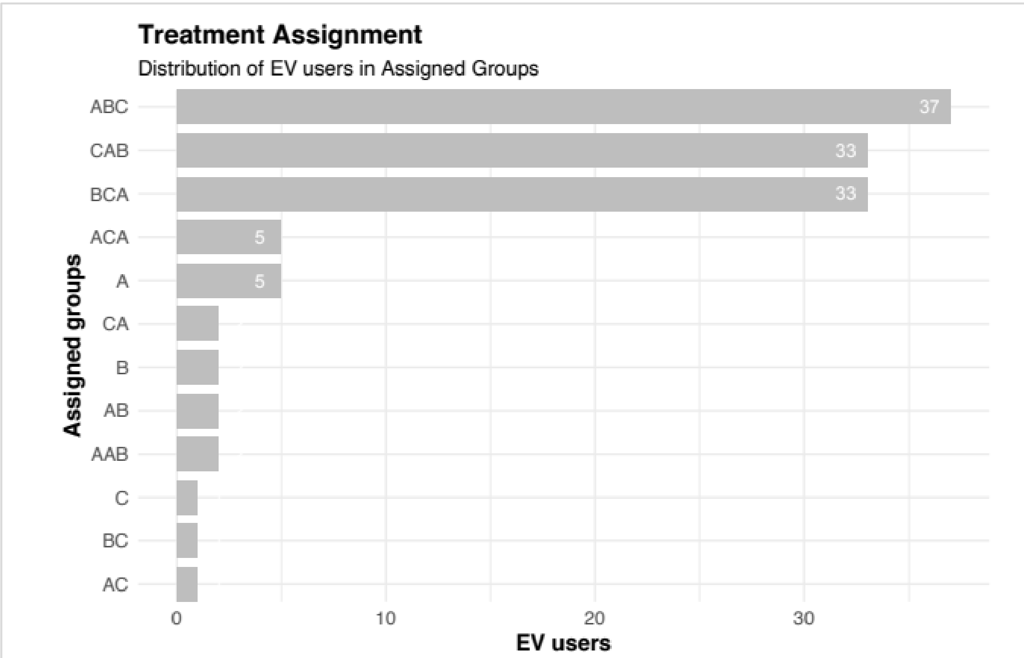
As a result, 103 of 124 (83%) study participants experienced all three different cost structures in six weeks.

A minority of 21 participants – who registered after the study began – were assigned to groups at random ending up experiencing fewer cost groups. The randomisation of users into groups was stratified by individual consumption levels, quantified by the credits spent prior to the experiment. Therefore, the resulted groups had a balanced distribution of prior consumption.

Figure 24 illustrates the active sessions during the day for all six weeks. As can be seen, the charge-field exhibits peaks of occupancy in the morning and after lunchtime. The average occupancy ranges between six to nine active sessions (maximum capacity), with greater variation around 12:00 where in some days the active sessions drop to four (half-capacity).

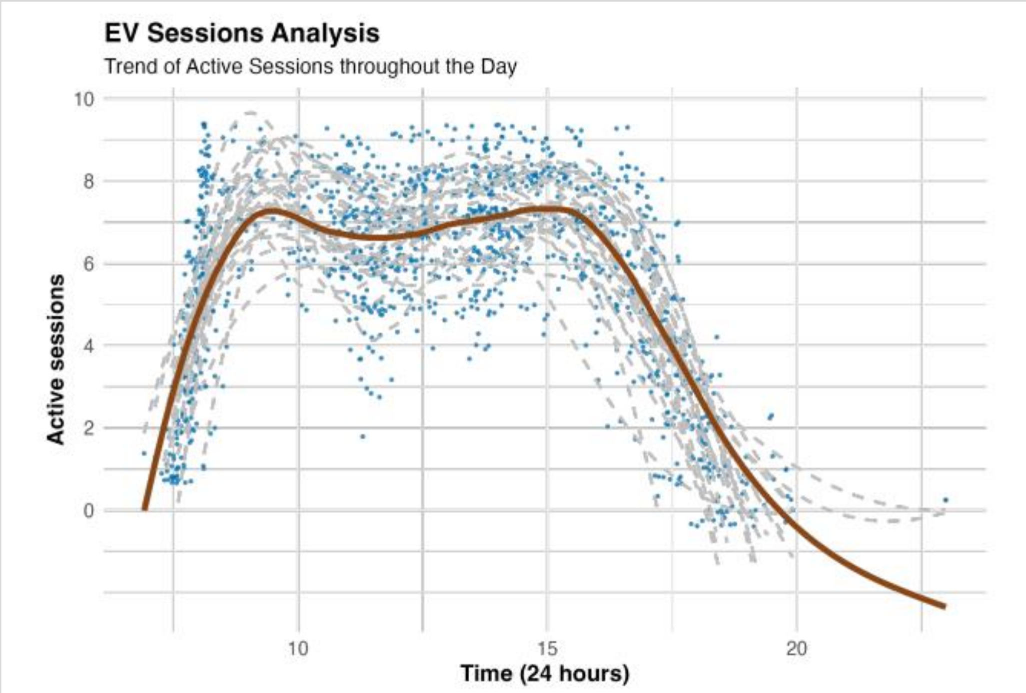
Each point (jittered) in Figure 24 illustrates a change in the number of active sessions during the day. Grey curves show the daily distribution. The red curve shows the average over the entire period.

Figure 23. Experimentation round #5 - Distribution of users by the combination of treatment groups experienced over the six-week experiment (W41-46).



Source: JRC, 2024

Figure 24. Experimentation round #5 (W41-46) - Active charging sessions during 24 hours.



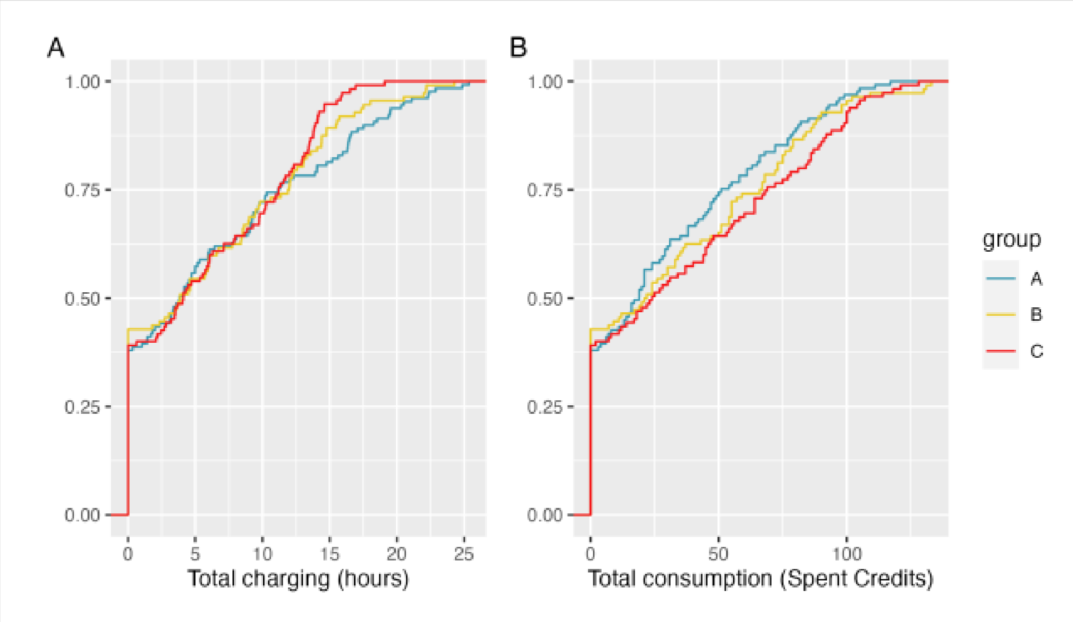
Source: JRC, 2024

Regression analysis

As a preliminary descriptive, Figure 25 presents the cumulative distribution of the total credits spent and charging time (in hours) for each treatment group. The graph illustrates the following key results:

- About a third of individuals spent no credits, reflecting an equal share of inactive users across treatments.
- Users in the high-cost groups spent the most credits, followed by the medium-cost group, and then the low-cost group.
- The difference in charging session duration across treatments was only significant in the top quartile, where fewer people charged for 15 hours or more in the high-cost group compared to the other groups.

Figure 25. Experimentation round #5 (W41-46) - Treatment differences.



Source: JRC, 2024

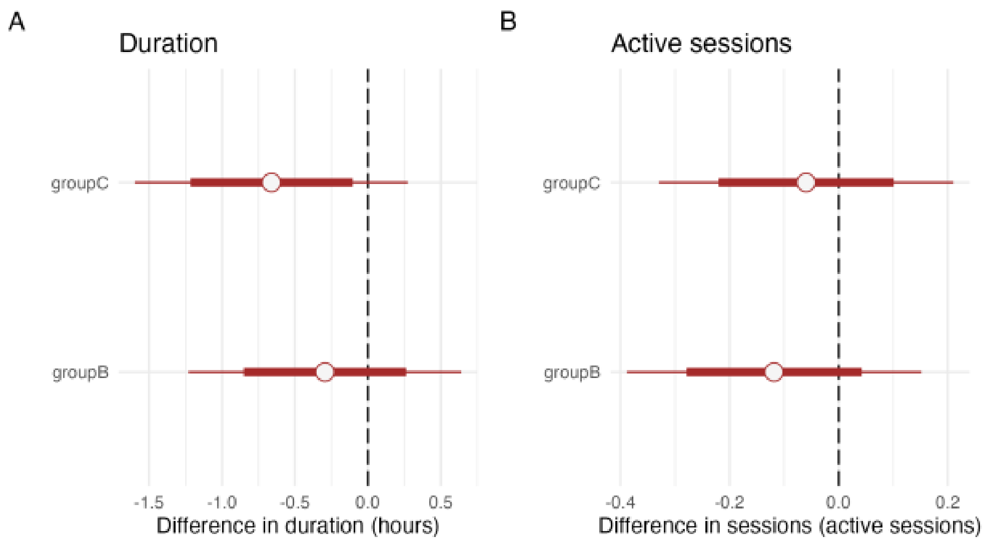
To evaluate the average treatment effect of varying the energy cost, we defined Y_{it} as the outcome measured at each period $t = 1, 2, 3$ for each user $i = 1, 2, \ldots, N$. The outcomes of interest include the total number of sessions, total credits spent, and total session duration in hours. Then the multiple linear regression was used to estimate the effect of our interventions on the conditional expected outcome:

$$E[y_{it}] = \alpha + \beta_i + \sum \tau_j D_{ijt} + period_t$$

where α is a constant, β_i denotes the effect of individual unobserved characteristics, including car type and commuting habits, D_{ijt} is the assignment of cost schedule *j* to individual *i* at time *t*; and $period_t$ denotes time fixed effects, i.e. unobserved factors constant within each period. In this regression, the parameter τ_j denotes the average treatment effect of the cost *j* relative to low cost, with *j* being medium or high cost.

Figure 26 illustrates the estimated average treatment effect of switching from a low (omitted category) to a high or medium credit schedule. Switching to higher credit schedules has a negative effect on session duration, with an average duration that drops by more than half hour (-0.5) in the High group and by -0.25 in the medium group. However, these differences are not statistically significant. Similarly, no statistically significant difference was detected in terms of active sessions.

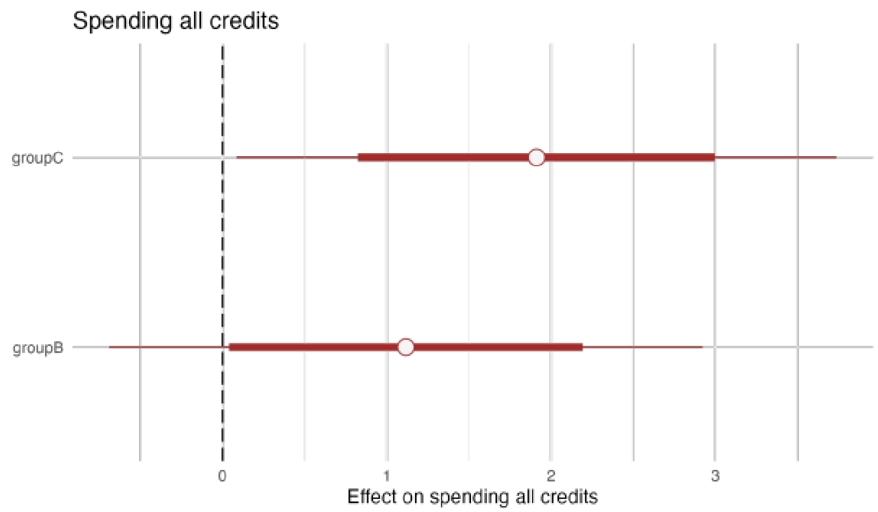
Figure 26. Experimentation round #5 - Estimates, standard errors and 90% confidence Intervals for the average difference in duration (A) and number of active sessions (B) between the low credit schedule (group A) and the medium (group B) and high (group C) credit schemes. The low credit schedule was omitted because it serves as the reference group in the regression model.



Source: JRC, 2024

Finally, Figure 27 displays the regression coefficients for a logistic model on the probability of consuming all the credits during the period. There is a statistically significant effect of switching from the low (the baseline) to the high credit schedule (group C), that is a positive and significant difference. Specifically, those in the high credit schedule were up to 25% more likely to consume all the credits in a given period. As for the models above, this specification also includes individual and period effects, thus adjusting for unobserved differences among individuals or between periods.

Figure 27. Experimentation round #5 - Estimates, standard errors and 90% confidence Intervals for the average effect of spending all credits between the low credit schedule (omitted) and the other groups [groupB = medium credit; groupC= high credit scheme].



Source: JRC, 2024

3.5.3.3 Discussion on the main findings

We conducted a randomised controlled trial to investigate how EV owners respond to different incentives for charging their cars at work, using a credit system with high, medium, and low credit schedule.

Switching from a low to a high credit system led to a decrease in the average session duration, to an increase in credits spent on average, and to less energy consumption. This evidence was statistically significant in the first weeks of the experiment (W35-W40) while lost some significance in the following weeks, likely due to the small sample size and the high fraction of inactive users.

The high-cost plan reduced session duration mainly for users with extreme values of energy "pulled", specifically for consumption above 12 hours per week. Additionally, users in the high credit group were more likely to use all their credits. This suggests that high-consumption users in the high-cost plan quickly reached their budget constraints, limiting their session duration.

These findings suggest little elasticity of consumers in response to the credit schedule and indicate that the impact of switching to a more costly credit system are not homogeneous but primarily affects top consumers. The top consumers might have either vehicles with larger battery capacity (although increased charging power might expedite the charging process, this was not the case in this particular round) or limited opportunities to charge at home.

Understanding how the credit system affects different people in the workplace remains a topic for future research.

4 Way forward

The project experimentations are still ongoing and planned to continue during 2024. Two new features will be added to enhance user experience, i.e.:

1. **User's personal area**, that will display information on the user's registered vehicle and latest charging sessions, as well as the number of (remaining) available credits;

2. **Parking spot's booking system**, which would allow users to reserve one of the available charging points 15 minutes in advance from the charging session's starting time.

More details on the new features will be provided in a separate report.

A new **demand-driven credit scheme** will also be introduced, whereby tariffs (in credits) will be adjusted based on the daily distribution of energy demand by users.

This experimentation will aim to better understand user behaviour and responses to varying tariffs throughout the day, as well as attempt to address the already highlighted behavioural issue of undue occupancy while increasing the total amount of energy delivered for EV charging.

5 Conclusions

In order to contribute to the objective of improving the EU's charging infrastructure for electric vehicles (EVs), and in an effort to anticipate innovative solutions related to the European Green Deal on areas such as smart grids, demand response and renewable electricity integration into the grid, in the last 2.5 years the JRC Living Lab for testing Digital Energy Solutions (DES-Lab) has been conducting research by testing and deploying smart charging systems for EVs and their impact on the use by staff.

Exploiting the characteristics of PRISM, a customisable wallbox provided by the Italian start-up Silla Industries under a non-monetary collaboration agreement with the JRC, the smart charging research project aimed to study the impact of smart charging systems on user experience, staff behaviour, and energy savings, and to investigate the behaviours and choices of EV owners in response to various incentive schemes for utilising workplace charging stations.

The key findings from the experimentation rounds carried out from September 2022 until December 2023 are provided in the following and are summarised in Table 10.

The use of the PRISM charging points has seen a continuous increase by JRC staff since September 2022. More than 120 JRC colleagues have adhered to the project, with approximately half of them considered as regular users.

Both energy delivered and effective charging time have also experienced a substantial increase over time, but a number of issues related to the efficient use of energy and compliance with the use of the charge-field have been detected during the experimentation sessions.

In particular, **two main behavioural obstacles** seemed to affect the optimal use of the charging points, i.e.:

- Some users charged their EVs multiple times in a day, thus not following the rules.
- Others left their vehicles plugged in beyond the maximum allowed time, thereby preventing access for others. Reducing the maximum allowed time per charging session seemed to correlate with a higher incidence of prolonged **undue occupancy of the charging points**. The 4-hour maximum charging option was found to have the least undue occupancy. Shorter maximum charging times resulted in increased undue occupancy due to staff's inability to physically reach the charging station and unplug their vehicles in the middle of the morning / afternoon.
- most users charged their vehicles in the morning or afternoon, despite peak PV production during lunchtime, resulting in **under-utilisation of the available renewable energy**.

Therefore, **better adherence to the rules for fair use of the chargers was required**, as well as **greater awareness of the optimal timing for charging** during the central hours of the day in order to maximise the (virtual) use of renewable energy for electric vehicles.

These findings also highlighted the **need for improved user coordination**. Messaging conveyed to users via signage at the charge-field and its single charging stations, e-mails and posts on Connected was therefore refined.

The **impact of behaviourally-informed communication** on undue occupancy and use of PV-produced electricity for EV charging was extremely limited, thus not providing the necessary leverage to shift users' charging habits. **Relying solely on information was deemed insufficient to drive significant behavioural changes** in the context of the PRISM project.

The subsequent **implementation of an RFID system** for accessing the charging stations and the **introduction of a flat new credit/penalty scheme** proved to be more effective, resulting in reduced undue occupancy of the charging spots and in a more efficient utilisation of the electricity produced by PV panels. As such, they may represent a valuable method to be implemented for future payment of EV charging sessions.

Ultimately, the PRISM research project investigated **the behaviours and choices of EV owners in response to various incentive schemes** for utilising a workplace charging station. A **two-tiered credit scheme** was introduced to understand how different pricing schemes might affect users and the extent to which a tiered credit approach might influence user experience.

Results suggested **little elasticity of consumers to the credit schedule** and that the effects of switching to a more costly credit system were not homogeneous and seemed to affect mainly the top consumers.

Understanding how the credit system affects different people in the workplace therefore remains a topic for future research.

Experimentations are still ongoing. A new session was initiated in March 2024 investigating user behaviour in relation to the use of a demand-driven credit scheme. The results of this new experimentation session will be published in a separate report.

Table 10. Summary of research objectives and key findings from the PRISM experimentation rounds 2022-2023.

Experimentation round	**Research question(s)**	**Main findings**
Round #1 – Static supply modality (Sept 22– Nov 22)	– To register users' behaviour in relation to different electricity supply conditions; – To test the effectiveness of different communication systems on users' behaviour.	– The total energy delivered exhibited a consistent increase over the entire 9-week experimentation period. – The total effective charging time also demonstrated an upward trend, indicating an overall improvement in user behaviour throughout the experimentation period. – A reduction in the maximum allowable time for each charging session appeared to be associated to a higher incidence of prolonged undue occupancy of the charging points. Some employees with EV in charging mode may struggle to break their half-day work routine when asked to charge for less than 4 hours.
Round #2 – Dynamic set-up (Nov 22- Feb 23)	Can we charge our EVs using the energy produced by the PVs installed in via Grecia? [Maximisation of the use of PV-generated energy to charging EVs, while also studying user behaviour and determining the most suitable maximum charging time for	– At the peak of electricity production from PV panels, a decrease in consumption is detected, resulting in underutilisation of the renewable energy available to the EVs mainly due to users leaving their cars plugged in beyond the maximum time allowed during the central hours of the day. – 58% peak in undue slot occupancy during the hours of maximum PV production. It is evident

	JRC staff using PRISMs during PV production]	that the rules for fair use of the PRISM chargers were not respected. – This may be explained by the fact that the 4-hour charging session ends on average around noon, and that this coincides with lunch break, when EV owners pick up their vehicles, or that users overlook their responsibility to vacate the charging slots around lunchtime. – Data indicate a clear correlation between the reduction in the maximum allowed charging time per session (2 hours) and a significantly higher rate of undue occupancy of the charging points. – The shorter the maximum allowed charging time, the higher the percentage of undue occupancy. This trend could potentially be linked to the highest concentration of physical and virtual meetings around 11 am. – The maximum allowed charging time should typically fit half a work day, in order to not disturb staff from their normal working routine. – Multiple charging sessions from the same EV owners in one day were also observed. – Overall, there is need for better adherence to the rules for fair use of PRISM chargers, as well as greater awareness of the optimal timing for charging during the central hours of the day in order to maximise the use of renewable energy for electric vehicles.
Round #3 – Behaviourally-informed communication (Feb 23 – Apr 23)	Can we reduce unnecessary occupancy of EVs at the charge-field through an ad-hoc communication strategy?	– No significant behavioural changes post intervention, likely due to statistical limitations and other factors. – There is a possibility that the information prompted a behavioural change, but if there was an effect, it was likely small and not detectable with the limited sample size. – Relying solely on information was insufficient to drive significant behavioural.
Round #4 – Use of RFID & (flat) credit system (May 23 – Jul 23)	– How can we further decrease undue occupancy? – How can we increase turnover among users, allowing max one charge per day?	– The introduction of the RFID system and of the new credit/penalty scheme have led to a reduction in undue occupancy of the charging spots and may represent a valuable method to be implemented for future payment of EV charging sessions.
Round #5 – Two-tiered credit system (Sept 23 – Dec 23)	– How do different pricing schemes affect users? – To what degree do the extended session duration	– Switching from a low to a high credit system led to a decrease in the average session duration, to an increase in credits spent on average, and to less energy consumption. This evidence was statistically significant in the first weeks of the

	and tiered credit approach affect user experience?	experiment (W35-W40) while lost some significance in the following weeks, likely due to the small sample size and the high fraction of inactive users. – The high-cost plan reduced session duration mainly for users with extreme values of energy "pulled", specifically for consumption above 12 hours per week. – Users in the high credit group were more likely to use all their credits, suggesting that high-consumption users in the high-cost plan quickly reached their budget constraints, limiting their session duration. – Findings suggest little elasticity of consumers in response to the credit schedule and indicate that the impact of switching to a more costly credit system are not homogeneous but primarily affects top consumers. – The top consumers might have either vehicles with larger battery capacity or limited opportunities to charge at home. – Understanding how the credit system affects different people in the workplace remains a topic for future research.

Source: JRC DES-Lab, 2024

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[3] Tarantola, S., Carbotti, A., De Ambrosis, L., Ferretti, F., Goded, I., Castelletta, R., *Pilot project for charging electric vehicles on the Ispra site – First results from the Living Lab for testing Digital Energy Solutions*, European Commission, 2023, JRC133268.

To access report [3], please contact the corresponding author by sending an e-mail to JRC-Energy-Living-Lab@ec.europa.eu.

List of abbreviations and definitions

Abbreviations	Definitions
A	Ampere (Unit of electrical current in the International System of Units)
AC	Alternating Current
CCBI	Competence Centre on Behavioural Insights
DES-Lab	Living Lab for testing Digital Energy Solutions
EMC	Electromagnetic Compatibility
EU	European Union
EV	Electric Vehicle
JRC	Joint Research Centre of the European Commission
KPI	Key Performance Indicator
kWh	kiloWatt-hour (Unit of energy used to measure the amount of electricity consumed over time. The amount of energy consumed by a 1000-Watt appliance for one hour)
NET1	EC internet
PV	Photovoltaic (panels)
RES	Renewable Energy Sources
RFID	Radio Frequency Identification
SMARTEN	*Smart Energy Solutions and Communities*, the institutional Workprogramme Project of JRC running the DES-Lab
Undue	Excessive or unwarranted; unjust, improper, or illegal [definition taken from Collins dictionary] In the context of the Smart Charging project, the undue occupancy of the parking spot refers to occupying the spot either beyond the maximum allowed time or after the EV has reached full charge.

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