Flexible energy systems Leveraging the Optimal integration of EVs deployment Wave

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Deliverable 2.4

Recommendations for demonstration projects

Authors:
Madlen Günther, Bettina Kämpfe, Lana Mohr & Daniel Trommler
[Chemnitz University of Technology (TUC)]

Denise Sogemeier & Ingrid Bohmann
[BMW]

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List of Acronyms

Acronym	Meaning
BEV	Battery Electric Vehicle
EV	Electric Vehicle
M	Mean
NUIM	National University of Ireland Maynooth
SD	Standard Deviation
SOC	State of Charge
SPI	Spirii
TUC	Technische Universität Chemnitz
RES	Renewable Energy Source
UCD	University College Dublin
UI	User Interface
UX	User Experience
V1G	Vehicle on Grid (unidirectional smart charging)
V2G	Vehicle to Grid
V2H	Vehicle to Home
V2X	Vehicle to Everything
WG	Working Group
WP	Work Package

Executive Summary

As the title of deliverable D2.4 (Recommendations for demonstration projects) promises, the aim of D2.4 is to provide recommendations for the design of the FLOW demonstration projects and testbeds to meet user preferences and requirements. Special emphasis is placed on the presentation of information and the design of intelligent charging applications.

Therefore, the first part (section 2) of D2.4 summarises general recommendations derived from several studies within task T2.3., that focus on the basic requirements that need to be met:

(1) Users need a basic understanding of smart charging.
(2) Users need access to a variety of information.
(3) Users need to be able to monitor and control their own charging processes.

Charging apps offer the opportunity to provide specific user-related information and feedback, and allow users to monitor and control their own charging processes. Based on desk research, prototyping, and evaluation studies, we derived recommendations for a user-centred charging app**.** These recommendations relate to the design of the app and the presentation of information within a smart charging app. Thus, a smart charging app should have a minimalist design with a clear layout and provide transparency through visualisation and presentation of various data. In addition, we make recommendations for specific charging features to give the users more and easy control over the charging process with a special focus on personal needs. Finally, we outline an all-in-one solution.

As the general recommendations need to be applicable to public charging apps, the sections 3, 4, and 5 provide detailed recommendations for the design of smart charging apps for public charging scenarios, with reference to use cases in Menorca, Copenhagen, and Dublin.

In section 3, we present a study that investigates whether the willingness to participate in smart charging practices and the acceptance of smart charging can be promoted by providing appropriate information to the user. This study shows that participants' intention to use smart charging in the Menorca setting can be significantly increased by appropriate HMI design with information processing tailored to the user. The presentation formats tested (information, storytelling and statistics) are equally useful. Therefore, it is recommended to provide meaningful information on the benefits of smart charging, to include feedback on individual energy consumption behaviour and to add gamification elements.

Section 4 evaluates the Spirii Go app that can be utilised at the demo site greater Copenhagen and assesses Spirii Go’s smart charging potential. The results show that users found Spirii Go quite usable and satisfactory but also indicated room for improvements in terms of usability. Most of the usability issues mentioned by users are reflected in or can be solved following the recommendations for all test beds and demo sites. Regarding smart charging features, Spirii Go partially met the requirements for the demo site Greater Copenhagen and can be seen as a good starting point for further enhancements.

Section 5 analyses user requirements for an information and communication tool that would improve the availability of charging and parking facilities on the Maynooth and UCD campuses in Dublin. Such a tool should provide certainty and plannability for the use of charging stations. In order to improve the availability of charging stations, the tool should enable the exchange of information and integrate a booking system.

1. Background and Objectives

The objective of D2.4 is to provide recommendations for the design of testbeds and demonstration projects to fulfil user preferences and requirements. There is evidence in the literature that user preferences depend on smart charging use cases and context of use. Kämpfe et al. (2022) found that participants introduced to a V2H use case that optimised their private consumption placed more emphasis on environmental benefits, energy and cost savings, and increased autarky, whereas participants in a V2G business use case (intraday trading) focused on earning money, grid stabilisation by providing energy to it, and societal benefits. The study also identified differences between the scenarios in terms of concerns, as concerns towards data security were only mentioned in the intraday trading use case. The results of FLOW T2.2.2 also showed differences between charging concepts and an influence of EV charging experience in terms of perceived criticality of data disclosure and perceived risks (Günther et al., 2024).

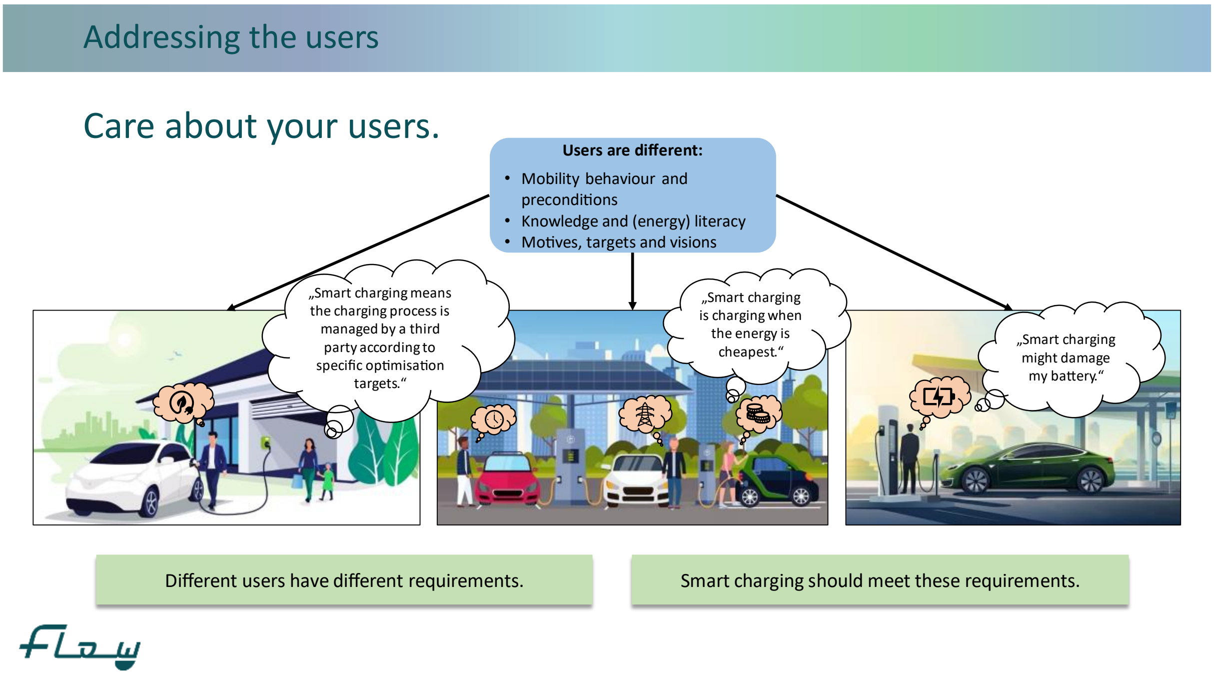


Figure 1. Different preferences and concerns of smart charging users. (presented at V2X Cluster WG2 workshop, June 2024)

In the FLOW project, there are five different demos and testbeds (WP6 and WP7), four of which involve end-users in smart charging. The use cases to be run in these field tests are quite different. For example, they vary in terms of usage contexts (private, public, semi-public), V2X concepts and objectives (V1G, V2G, V2B, shared parking and charging), and user groups. What they all have in common is that users interact with the intelligent charging system through a user interface (UI). Therefore, firstly, users need a basic understanding of the charging system, and secondly, the development of UIs must take into account specific user preferences and requirements, while at the same time motivating users to use smart charging. To this end, D2.4 summarises the results of the desk research and general UI studies in T2.3, complemented by a focus group study. In order to provide specific recommendations for the UIs in the testbeds and demos and to focus on the open issues, D2.4

supplements the results of additional studies within T2.4 that have a deeper focus on the specific testbeds:

- Evaluation study of the Spirii Go App, including requirements for the demo site greater Copenhagen
- User requirements analysis on a tool to improve the availability of charging and parking facilities on the Dublin campuses in Maynooth and UCD
- Development and evaluation of a gamification-based prototype for a touristic setting as in Menorca to analyse the impact of different information presentation and HMI designs on users' smart charging intention

2. General recommendations

The general recommendations are derived from several studies within tasks T2.3. We presented a summary of the results to the FLOW partners as well as to interested partners of the sister projects at the first online workshop of the V2X Cluster Working Group 2 *Consumer Perspective* in June 2024. The first part of the workshop focused on charging from the user's perspective and derived recommendations on how to address the user. *Information* was identified as a key factor. A smart charging app is one way to provide users with the relevant information. Therefore, but not only, T2.3 aimed to identify requirements for smart charging apps. Most of the studies within T2.3 are already reported in D2.3, such as the desk research and the resulting smart charging app prototype, its validation by expert evaluation, and an experimental app user study. Based on the results, the smart charging prototype was improved and then tested in a laboratory study and finally evaluated in a user group discussion. The general recommendations in D2.4 are therefore initially a summary of the recommendations from the V2X workshop and D2.3, extended by the user testing of the enhanced prototype and the focus group.

2.1. Engaging the user in smart charging

To enable users to use smart charging, the users need to have certain basic information about the EV battery status, technical (compatibility) parameters of the charging infrastructure, the charging costs, and others (Figure 2). In addition, users may also want to know more details about smart charging, such as the user's individual electricity consumption (Paetz et al., 2012; Paetz et al., 2011; Marxen et al., 2022), real-time electricity price data and daily tariff forecasts (Paetz et al., 2012; Paetz et al.; Geelen et al., 2013), the financial consequences, e.g., cost savings (Paetz et al., 2011; Delmonte et al., 2020) or the respective carbon footprint of a user (Marxen et al., 2022), and the availability of locally generated energy (Geelen et al., 2013).

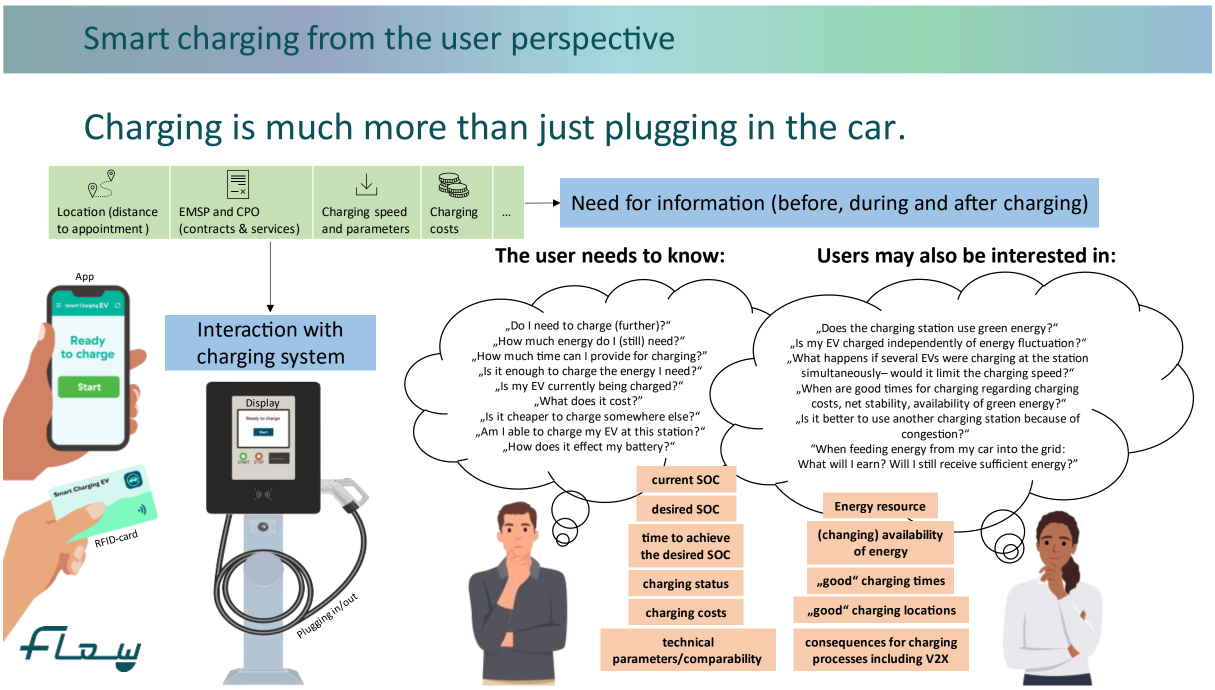


Figure 2. Information needed by the user. (presented at V2X Cluster WG2 workshop, June 2024)

Even during the charging process, it is very important to provide users with detailed information on the current and future status of the charging process, such as charging plans and the underlying data for its calculation (weather data, price forecasts, grid capacity utilisation, etc.). Information and transparency through feedback can help create a correct understanding of the charging system. This will avoid misinterpretations and promote positive user experiences (Kämpfe & Braun, 2023).

The clear recommendations for setting up demos and testbeds are:

- Inform and educate users about smart charging (even if it is being tested in the background).
- Support the users.

Figure 3 summarises where and how this can occur. General information can be provided almost anywhere. Explanations can be given through flyers, marketing campaigns, websites, or in-app. Similarly, a support service should be established that is easily accessible from anywhere. Besides, charging apps offer the opportunity to provide specific user-related information and feedback. It is therefore particularly important to consider user demands when developing smart charging apps. For this reason, we will focus on smart charging apps in the following.

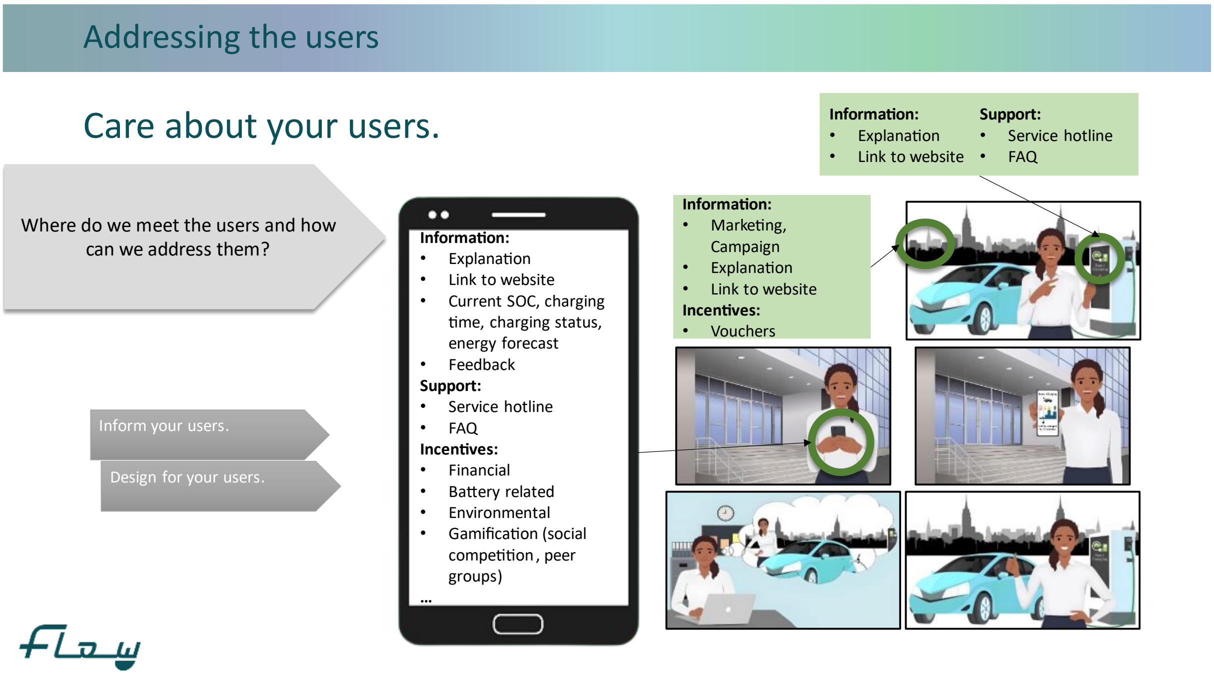


Figure 3. How to address and inform users. (presented at V2X Cluster WG2 workshop, June 2024)

2.2. Recommendations from D2.3

The results of a desk research, an expert evaluation of a developed prototypical smart charging app, and an experimental app user study (T2.3) show the necessity for the development of apps that offer a wide range of smart charging features for public and private charging. Smart charging apps should meet the following user requirements:

- **Give users control and autonomy**: Features such as instant or immediate charging and charging schedules allow users to intervene in the automated smart charging process. The ability to set a departure time and charging limit allows users to take control of the charging process.

- **Create clarity in complexity**: Apps should be clear in design, structure, and icons to be intuitive and easy to use.
- **Provide transparency** about the charging process itself, as well as financial aspects (pricing and cost savings) and environmental aspects (CO_2 savings).
- **Allow personalisation**, such as customisation of charging preferences and schedules.
- **Consider integrating all vehicle functions** (beyond smart charging functions) into a single app to enhance convenience for users.

2.3. User Study: Evaluation of the modified prototypical smart charging app

2.3.1. Aim

Within the scope of this project, we developed a prototypical smart charging app based on extensive literature research, including current research efforts and smart charging solutions. In an expert evaluation, we gained insights from eight experts for the future development of this prototype (see D2.3 for reference). These recommendations were then implemented in the prototype. The aim of the user study at hand was to evaluate the usability, acceptance, and trustworthiness of the improved prototypical smart charging app. From this, recommendations for the testbeds and demos are concretised.

2.3.2. Methodology

<u>Study material</u>

The prototype encompassed five functional areas: (1) *Onboarding and Personalisation*, (2) *Main screen*, (3) *Spontaneous Charging (Instant Charging*, *Spontaneous Trip* and *Charging Boost)*, (4) *Routines (Charging Schedules* and *Charging Modes*), (5) *Charging History* and *Charging Statistics*.

Main screen. The main screen was developed with the intention that it should permanently display important information, such as vehicle status and charging settings, but at the same time be customisable. It is divided into a static area with vehicle and charging information and a customable area with further information. A navigation bar provides quick access to various app menus. The three *Spontaneous Charging* functions *Spontaneous Trip, Charging Boost* and *Instant Charging* could be accessed through the main screen. While the *Instant Charging* feature provides users with a sense of control, ensuring they always have a certain level of battery charge available, the other two features address the dynamic nature of electric vehicle usage:

Charging Boost. The *Charging Boost* feature is designed to give the user control over the charging process. It enables uncontrolled charging as with conventional charging apps and offers an 'override' function to temporarily deactivate smart charging. *Charging Boost* allows users to quickly charge a certain amount of energy to meet their immediate energy needs without changing regular charging schedules, and to limit the amount of energy to be charged in unfavourable charging conditions, such as high prices at motorway service stations.

Spontaneous Trip. *Spontaneous Trip* is an advanced planning feature that allows the creation of a one-off charging plan for different events, such as business trips or weekend trips. Planned changes to routine charging schedules for specific days, including different departure times or target charging states, can be set.

Instant Charging. If the state of charge is low, the *Instant Charging* feature is designed to restore a minimum state of charge as an emergency reserve as soon as the vehicle is connected to a charging station/wallbox. Only after this is reached the stored charging schedules will be considered. This should provide a sense of security for urgent, unforeseen trips.

Charging Schedules. Users can set up routines as *Charging Schedules* and customise each charging schedule with a label, specific days of the week, departure time as well as charging mode. Charging schedules can be set for times when the vehicle is available for charging and can be easily activated or deactivated.

Charging Modes. There are three available charging modes to choose from: *Eco Mode*, *Savings Mode*, *Self-Supply Mode.*

Charging History and *Statistics.* These functions offer users a comprehensive overview of their past charging events in both a summary and a detailed view.

For a more detailed description of the prototypical app see FLOW Deliverable D2.3.

Based on the results of an expert evaluation and an additional experimental user study (please see D2.3 for references), we made adjustments to the prototype. We placed particular emphasis on the key features *Spontaneous Trip*, *Charging Boost* and *Instant Charging* including the visualisation of the state of charge (charging bar). Figure 4 shows an adjusted screen. The changes were made in order to follow the recommendations derived from D2.3, such as creating clarity in complexity by (a) providing supplementary information, e.g., explanatory texts, or additional help menus, and (b) increasing the distinctiveness and uniqueness of the visuals.

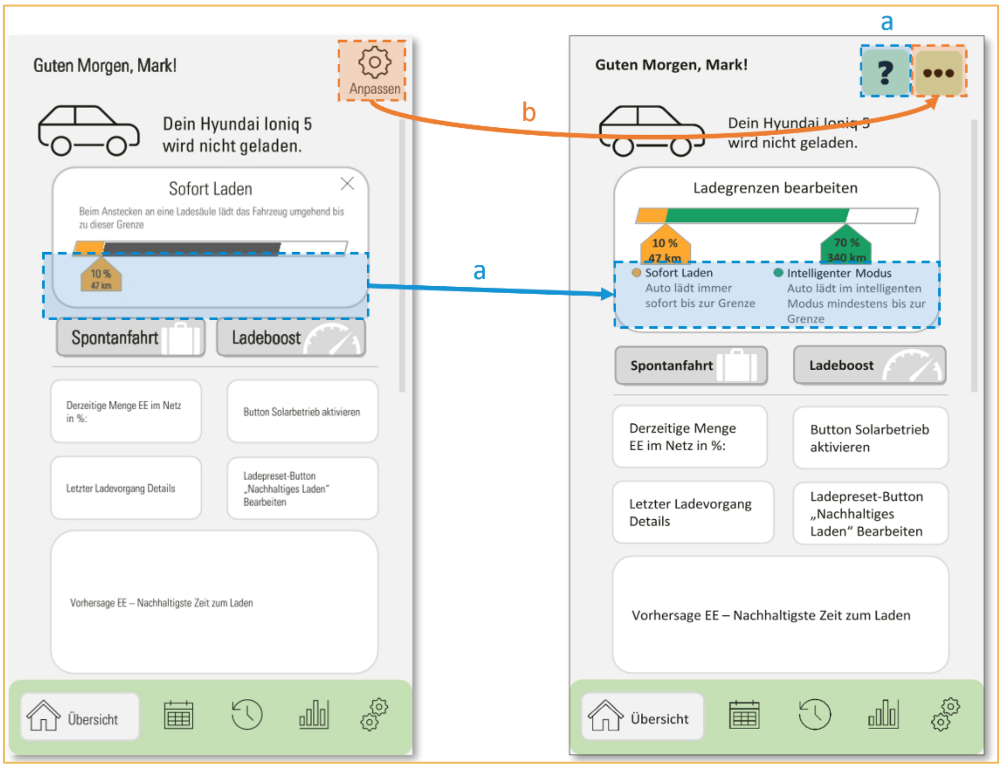


Figure 4. Exemplary representation of the changes made to the prototype (main screen): the redesigned charging bar.

<u>Study design and procedure</u>

To evaluate the advanced prototype, a laboratory user study was conducted in Chemnitz, Germany, from March 25th to May 17th, 2024, in which test users interacted with the prototypical app. All users used the same app version and solved the same tasks. The study procedure began with obtaining informed consent from participants, providing them with written information about the study objectives (including a definition of smart charging), and with participants completing a pre-test questionnaire. The evaluation of the prototypical smart charging app consisted of several stages. First, participants were given a guided tour of the app prototype, lasting approximately three minutes. During this time, they were asked about their initial impressions of the main screen (including the charging bar) and their associations with the key features, such as *Instant Charging*, *Spontaneous Trip*, and *Charging Boost*. The responses to these questions were not evaluated by the researcher. The objective of this query was to ascertain that all participants were operating from the same baseline level of knowledge. We provided each participant with a concise description of each feature to ensure a uniform understanding. After the initial walkthrough, participants engaged in hands-on interactions with the prototype app, completing specific tasks and use cases representative of everyday situations. The specific tasks are presented in Table 1. During these interactions, participants were asked to verbalise their thought processes and observations as they engaged with the prototype app. Their interactions were recorded through audio and video recordings of the mobile screen. Following the interactive session, participants evaluated the app using several self-report questionnaires. The study concluded with a final interview, in which participants discussed the advantages and disadvantages of the app, focusing on the app's positive aspects, potential for improvement, and providing specific recommendations for enhancement.

Table 1. Overview of specific tasks and use cases.

Number	Instruction
1	Check the current state of charge of your vehicle as a percentage.
2	Navigate to the menu where you can change the target charging state for *Instant Charging*.
3	Check which charging target the smart charging mode is set to.
4	Change the charging plan **once**. Define the planned departure time as 9 a.m. tomorrow with a target charging state of 70%.
5	Change the **regular** charging schedules so that your car has a range of around 30 km available from Monday to Friday at 8 a.m.
6	You are on the motorway and want to charge your vehicle as fully as possible for half an hour. Change the charging settings accordingly. Then you want to go back to charging according to your charging schedule.
7	Find out when your vehicle will next be charged.
8	Check the amount of electricity charged during the last charging process.
9	Check the price per kWh for the electricity charged during the last charging session in the smart charging app.
10	Check whether more instant or more smart charging has taken place in the last 7 days.
11	Check the amount of CO_2 emissions on the previous Saturday in the smart charging app.
12	In the smart charging app, check the financial savings in the last 7 days achieved by using the smart charging app.

Measures

We included several questionnaires in the pre-test (see) and for the evaluation of the prototype (see Table 3) to assess the constructs of interest. In addition to self-reported data, we collected behavioural data in the form of experimenter ratings (Forster, 2020). The experimenter rated participants' behaviour on a 5-point rating scale for user interaction success, ranging from 1 *no problem* to 5 *help of the experimenter*. We further employed the think-aloud-method during the evaluation of each app in order to capture the mental processes of the participants as they interacted with the apps. We asked the participants to verbalise their thoughts, intentions, and expectations during the interactions.

Table 2. Overview of pre-test items.

Construct	Scale/Items	Source
Affinity for technology	Affinity for Technology Interaction Scale	Franke et al., 2019
Environmental awareness	'People are too worried about the future of our environment.' 'People are too worried that human progress is damaging the environment.' (5-point Likert scale from *1 completely disagree* to 5 *completely agree*)	Own items from previous projects
Awareness of smart charging	'Are you already familiar with smart charging (intelligent charging, controlled charging) for electric vehicles?' (*Yes*/*No*)	Own item from previous projects
Knowledge and attitude towards smart charging	'In my opinion, controlled charging of electric vehicles offers significant added value compared to uncontrolled charging.' 'I think the controlled charging of electric vehicles is good.' 'Controlled charging of electric vehicles will be easy to use.' 'Controlled charging of electric vehicles is an uncomplicated technology.' 'I would favor the controlled charging of electric vehicles over uncontrolled charging.' 'I would like to use controlled charging of electric vehicles as often as possible.' (6-point Likert scale from 1 *not true at all* to 6 *completely true)*	Own items from previous projects
Actual use of electric vehicles	Kilometers driven in the previous year; 'Do you already have experience with electric vehicles (pure battery electric vehicles)?' (Single response: *No, none*; *Yes, I have driven an electric car once (e.g., test drive)*; *Yes, I occasionally drive an electric car (e.g., hire car)*; *Yes, I own an electric car myself*; *Other experience with electric vehicles* (open response text field)	Own item from previous projects
Actual use of smart charging or bidirectional charging	'Do you already use one of the following charging concepts for electric vehicles yourself?' (Multiple responses: *Yes, I use smart charging (intelligent charging, controlled charging); Yes, I use bidirectional charging; No)*	Own item from previous projects

Table 3. Overview of self-reported measures.

Construct	Scale	Source
Acceptance	Acceptance Scale	Van der Laan et al. (1997)
Usability	System Usability Scale (SUS)	Brooke (1996)
User Experience	User Experience Questionnaire (UEQ)	Laugwitz et al. (2008)
Trustworthiness	Facets of the System Trustworthiness Scale	Franke et al. (2015)

<u>Participants</u>

A total of *N* = 38 participants took part in the study, with *n* = 19 identifying as female and *n* = 19 identifying as male. The sample consisted of students or interns (*n* = 25), employees (*n* = 11), and pensioners (*n* = 2). The mean age of the sample was 31.0 years (*SD* = 14.28), and the participants were rather unexperienced with electric vehicles (60.52 % with no experience at all, 29.48 % drove an EV for either a test drive or as a rental). Only half of the participants were previously aware of the concept of smart charging. Of those who were aware of the term, only *n* = 5 individuals reported using smart charging.

2.3.3. Results

<u>Interactions</u>

The results of the behavioural data are illustrated in Figure 5, with the descriptive statistics presented in Table 4.

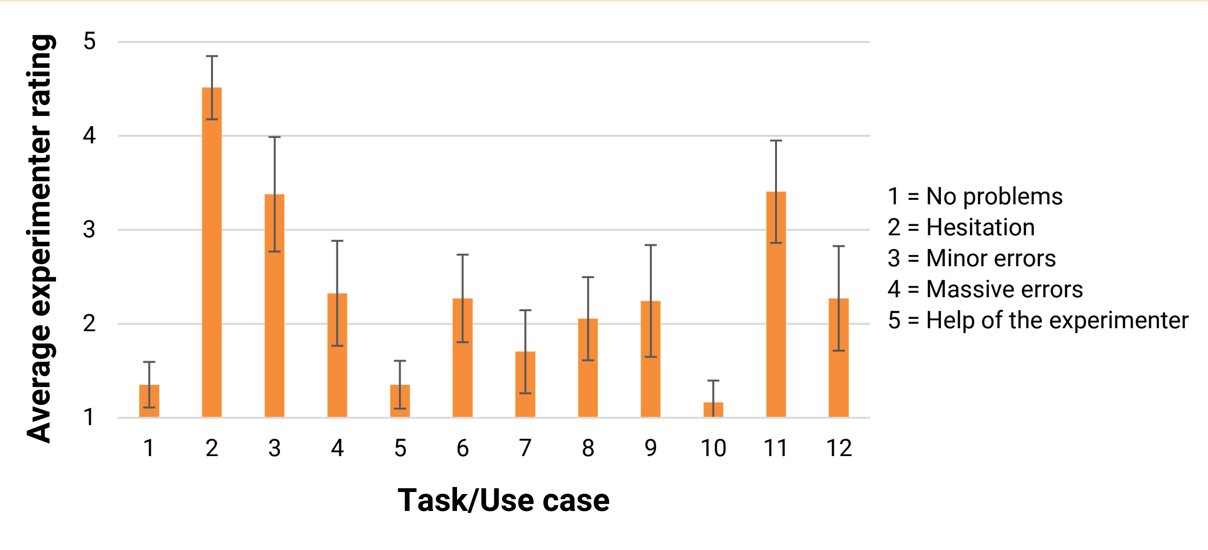


Figure 5. Mean value of the ratings of the different tasks.

The results demonstrate that the participants predominantly encountered difficulties with tasks 2, 3 and 11. Conversely, tasks 1, 5, and 10 were the least problematic. Additionally, the experimenters documented the issues participants encountered when interacting with the app. The most frequent issues encountered in each task are presented in Table 4.

Table 4. Descriptive statistics and typical problems for each task.

Task	*M*	*SD*	*Typical problems*
1	*1.35*	*0.75*	**- Lack of visibility of the charging bar***:* Participants did not initially recognise the charging bar and tried to open the extended menu instead. **- Uncertainty in interpreting the information:** Test subjects were unsure whether the displayed percentage was the correct answer.
2	*4.51*	*1.04*	- **Misinterpretation of the task:** Test subjects interpreted the task as meaning that they should open the *Charging Boost* menu. - **Uncertainty:** Test subjects were often unsure where they could make the relevant settings. Long searches and trying out various menu options (*Spontaneous Trip*, *Charging History*) were the result. - **Recognisability of the controls:** Test subjects did not recognise the slider as such and interpreted them as static displays.
3	*3.38*	*1.89*	- **Difficulty in finding the information:** Test subjects initially focussed on the *Routines* function or other areas of the app, although the relevant information could be found in the drop-down menu or target charging state settings. - **Uncertainty in interpreting the information:** Test subjects were unsure whether the information in the drop-down menu actually corresponded to the target charging state they were looking for. - **Search behaviour and exploration:** Test subjects searched extensively in various menus before finding the correct solution.
4	*2.32*	*1.73*	- **Confusion of functions:** Subjects had difficulty identifying the correct function (*Spontaneous Trip* vs. *Routines* function) for the task. - **Lack of clarity about the possibilities of the prototype functions:** Subjects attempted to make adjustments in the schedules. - **Uncertainty in the interpretation of the task:** test subjects were unsure whether the task was to be solved using *Schedules* or *Spontaneous Trip.*
5	*1.35*	*0.79*	- **Uncertainty due to the previous task:** Subjects were insecure because they had already solved the task in the previous task using the *Schedules*. - **Hesitant search behaviour:** Subjects were initially unsure where to find the solution (e.g. target charging state setting). - **Misjudgement of the menu structure:** Test subjects were unsure whether they would reach a new menu via *Schedules* heading in the *Routine* function.
6	*2.27*	*1.45*	- **Misinterpretation of the task:** Test subjects interpreted the task as meaning that they should set the target charging state as high as possible instead of the charging amount for a 30-minute charge. - **Confusion of functions:** Test subjects initially tried to solve the task using the *Spontaneous Trip* function instead of using the *Charging Boost*. - **Overlooking the charging time forecast:** Test subjects initially overlooked the information on the estimated charging time in the *Charging Boost* menu.
7	*1.70*	*1.37*	- **Naming departure times from timetables:** Test subjects named the departure times from the different timetables as an answer. - **Overlooking the information on the main screen:** Test subjects did not find the information and then continued to search in other areas of the app.
8	*2.05*	*1.37*	- Misuse **of the *Charging Statistics*:** Test subjects first searched in the statistics menu instead of in the *Charging History*.
9	*2.24*	*1.85*	- Misuse **of the *Charging Statistics*:** Test subjects first searched in the statistics menu instead of in the *Charging History*. - **Misinterpretation of price information:** Test subjects stated the full price instead of the price per kWh, even after they had opened the detailed view. - **Failure to use the detailed view:** Test subjects did not initially open the detailed view of the charging process but tried to determine the price elsewhere.

Task	***M***	***SD***	***Typical problems***
10	*1.16*	*0.73*	- **Misuse of the *Charging History*:** Test subjects searched for the information in the *Charging History* instead of in the *Charging Statistics*.
11	*3.41*	*1.69*	- **Problems finding and navigating to the relevant view:** Test subjects initially searched in other areas of the app (e.g., *Charging History*) or overlooked the buttons to switch between the statistics views. - **Comprehension problems when interpreting the diagram:** Test subjects were unsure when reading the diagram (bar vs. curve). - **Interaction problems with the app**: Test subjects tried to tap on bars or other elements to get more details. - **General uncertainty when reading the diagram**
12	*2.27*	*1.73*	- **Focussing on the diagram and overlooking the direct information:** Test subjects concentrated only on the diagram instead of paying attention to the exact information on savings in the upper half of the screen. - **Misinterpreting other information:** Test subjects mentioned the total expenditure or CO_2 savings. - **Searching in other app menus:** Test subjects searched in the *Charging History* or other functions.
Note: Higher mean values (M) represent higher experimenter ratings, indicating worse performance, i.e., having more trouble completing the tasks. The sample size for all tasks was *n* = 38.			

Questionnaire results

Participants rated the first impression of the prototypical app on a German school grading scale, with 1 = "*very good*", 2 = "*good*", 3 = "*satisfactory*", 4 = "*sufficient*", 5 = "*poor*", 6 = "*deficient*". On average, the prototypical app received a score of *M* = 1.90 (*SD* = 0.76). The relevant descriptive statistics for acceptance, usability, user experience, and trustworthiness of the prototype are listed in Table 5. The results show high values on both subscales of the Van der Laan Acceptance Scale.

Table 5. Descriptive statistics for each questionnaire.

Questionnaire and Subscale	***M***	***SD***	***Scale Ranges***
Van der Laan Acceptance Scale – Usefulness	*1.33*	*0.48*	-2 - +2
Van der Laan Acceptance Scale - Satisfying	*1.23*	*0.59*	-2 - +2
System Usability Scale	*77.63*	*16.22*	0 - 100
Facets of System Trustworthiness Scale	*5.02*	*0.75*	1 - 6
UEQ - Attractiveness	*1.71*	*0.82*	-3 - +3
UEQ- Efficiency	*1.53*	*0.87*	-3 - +3
UEQ - Perspicuity	*1.78*	*1.19*	-3 - +3
UEQ - Dependability	*1.91*	*0.72*	-3 - +3
UEQ – Stimulation	*1.44*	*0.75*	-3 - +3
UEQ – Novelty	*0.93*	*1.11*	-3 - +3
Note: Higher mean values (M) indicate higher ratings, i.e., a more positive attitude towards the system (i.e., higher acceptance, higher satisfaction, higher trust, higher user experience ratings). The scale range indicates the potential range of scores, with higher values denoting more positive ratings.			

Final evaluation

The positive and negative remarks made by the participants during the final interview are listed in Table 6.

Table 6. Participants' remarks during the final interview.

	Category	n	Comments
Positive comments	Clarity and intuitiveness	16	The app was found to be practical and clear.
		16	The app was perceived as intuitive and easy to use.
		15	The arrangement and structure of the functions were described as logical and in line with expectations.
	Display of information	8	The most important information, such as state of charge and kilometres, was directly visible on the main screen.
		4	The information on price, time, and savings was found to be helpful.
	Range of functions and flexibility	6	Additional functions such as *Spontaneous Trip* and *Charging Boost* were seen as useful additions.
		6	The ability to create and customise routines was rated as practical and flexible.
		4	The range of functions was perceived as comprehensive, but not overloaded.
	Aesthetics and customisability	5	The design (especially icons) of the app was perceived as appealing and aesthetically pleasing.
		5	Overall, the app was perceived as motivating (for saving) and fun.
		4	The graphical representation in the statistics was positively emphasised.
Negative Comments	Ease of use and Comprehension	12	Terms such as 'Spontaneous Trip' (rather: 'Single Journey', 'Extra Journey') and 'Charging Boost' (rather: 'Spontaneous Journey') were perceived as misleading by some users.
		6	Some controls were perceived as unintuitive or too small, e.g., the statistics switch.
	Display of information	6	Some of the labelling and diagrams in the statistics were found to be difficult to read or not meaningful enough.
	Range of functions and logic	7	Overall, the app was perceived by some as too complex and overloaded, especially for newcomers (especially the tile area; tutorial/video useful).
		6	There was a desire for additional functions such as charging recommendations, price limits, price forecasts, weather forecasts or pre-heating the car.
Further notes	Operation and input methods	1	Enable setting of departure times and target charging states via clock or slider input instead of numerical input.
	Integration of external data	1	Integrate a private solar system into the app and prioritise its surplus feed-in.
	Export function	1	Make statistics exportable, e.g., as a CSV file.
	Range of functions and flexibility	1	Additional functions such as *Spontaneous Trip* and *Charging Boost* were seen as useful additions.
	Fundamental functional logic	1	Smart charging should be preset and not have to be configured by the user.
		1	Optimisation of charging according to price rather than charging states.

2.3.4. Conclusion

The present study investigated the usability and user experience of a prototypical smart charging app with *N* = 38 users. In conclusion, the prototype has generally received positive feedback. Although user difficulties were observed in the individual interactions, the self-reported evaluation of the prototype was positive, as it scored high on all quantitative measurements including, acceptance, usability, user experience and trustworthiness. Complementary to the experts' feedback in the previous study presented in D2.3, the input from real users offered a more diverse range of perspectives, capturing the variability in how different users interact with the app. This diversity is crucial for identifying usability issues that might not be evident to experts who are more familiar with the domain. This comprehensive approach underscores the value of incorporating broad user feedback into the development and refinement of the prototype, leading to more user-centred and effective design solutions. The results of the user testing can enrich the recommendations from D2.3 as follows:

Give users control and autonomy **and** ***allow personalisation***

- **The app should accommodate flexible charging schedules and targets,** allowing for daily routines and exceptions, as well as various charging goals such as immediate charge limits for quickly restoring a minimum state of charge (SoC).

Create clarity in complexity

- **The app should feature a clear and organized layout.** This includes prominently displaying the charging bar and essential information, such as the next charging schedule, on the main screen. It is crucial to use clear function labels (e.g., 'Single Trip' for one-time exceptions) and intuitive symbols (e.g., a bar chart icon for the statistics menu).

Provide transparency

- **The app should clearly visualise when the vehicle is expected to charge and when the charging process is anticipated to be completed, or at the latest, finished**. Additionally, there should be a clear and concise visualisation of the charging targets (e.g., instant charging target, smart charging target) and the set schedules (routines and exceptions).
- **Regarding data, the app should present a variety of data related to the charging history and statistics,** placing them in close proximity within the menu structure. The statistics diagrams should be clear and not overloaded with information, and the charging history should be straightforward, with the option to access additional details via a submenu if necessary.

In addition to ***considering integrating all vehicle functions*** *(beyond smart charging functions) into a single app to enhance convenience for users*,

- **The app should enable connections with other apps and data sources,** such as weather forecasts and price predictions.

It is important to acknowledge certain limitations in this study. The use of a prototype app created in PowerPoint did not allow for real inputs or smooth window transitions. Additionally, the ability to provide a nuanced assessment of constructs like trust, which develop over extended app usage, was restricted.

2.4. Focus Groups: Requirements for smart charging and discussion about previous design drafts of a smart charging app

2.4.1. Aim

The first objective of the focus groups was to assess the existing functionality of the prototypical smart charging app. In particular, it was of interest how the features of the prototype were assessed in terms of acceptance and usefulness and whether the labelling and design of the functions were understandable and intuitive. Furthermore, suggestions for improving the features were to be developed, and it was clarified which findings from the user study should be considered in the further development of the app. The second objective of this study was to elaborate, which further functions could support smart charging (e.g., time and energy planning), and how these should be designed. Based on these insights, we derived recommendations for the testbeds and demos.

The current study aimed to address several critical research questions concerning the prototypical smart charging app. Firstly, how are the current functions of the app evaluated in terms of acceptance and usefulness by its users? Additionally, we seek to understand whether the labels and designs of these functions are perceived as clear and intuitive. Are there specific suggestions for improvements that users have proposed for the further development of these functions? Moreover, what insights from the user study should be considered in the ongoing development of the app to enhance its effectiveness? Secondly, the study explores potential additional functions that could support temporal and energy planning. What additional features could enhance smart charging, and how should these features be designed to meet user needs effectively? These questions aim to provide a comprehensive understanding of the current app's usability and identify opportunities for future enhancements.

2.4.2. Methodology

Study material

We used the same version of the prototypical app as for the laboratory study.

Study design and procedure

To answer the research questions, three focus groups of about two hours each were held at the premises of TUC in May 2024 with both experienced and inexperienced participants in electric vehicle driving and charging.

The focus groups commenced with a welcome and a round of introductions. The participants were then provided with an explanation of the concept of smart charging. The main part of the focus group was divided into three thematic segments. In the first segment, participants engaged in 15-minute small group discussions about their personal charging situations and their requirements for smart charging. They discussed their current charging setups and contemplated how they could utilize smart charging. Additionally, they identified the features that would be important to them in a smart charging app. The second segment involved a discussion about the existing design drafts of the prototypical smart charging app. This included 10-minute discussions on the key app menus such as the *main screen*, *Charging Schedules*, *Charging Boost*, *Spontaneous Trip*, and *Instant Charging* The moderator first explained the basic idea and structure of each menu or function, followed by an open discussion on the participants' initial impressions. This was then followed by a more detailed discussion on specific topics, some of which were derived from a previous user study. In the third segment, participants worked in small groups for 15 minutes and then engaged in a 20-minute discussion to generate new ideas for app functions. They were tasked with designing one or two selected ideas from the first segment using a smartphone template. After the third segment, the session ended, and the participants were dismissed. The focus group sessions lasted approximately two hours.

Participants

The target group involved people who own an electric vehicle, use it regularly, or intend to buy an electric vehicle in the next two years. A total of N = 22 participants took part in the focus groups with n = 3 identifying as female and n = 19 identifying as male. The sample consisted of students (n = 4), employees (n = 14), and pensioners (n = 4). The mean age of the sample was 46.0 years (SD = 16.82). All participants reported prior experience with electric vehicles, and 63.6% of the participants reported driving at least 5.000 km in the past 12 months. Almost three-quarters of the participants were previously aware of the concept of smart charging. Of those who were aware of the term, only n = 6 individuals reported using smart charging. Three different focus groups were conducted, each with around a third of the participants.

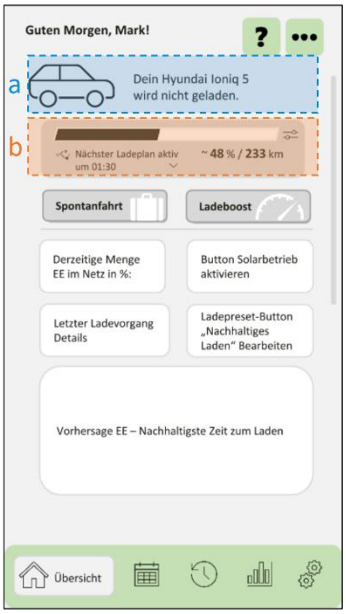
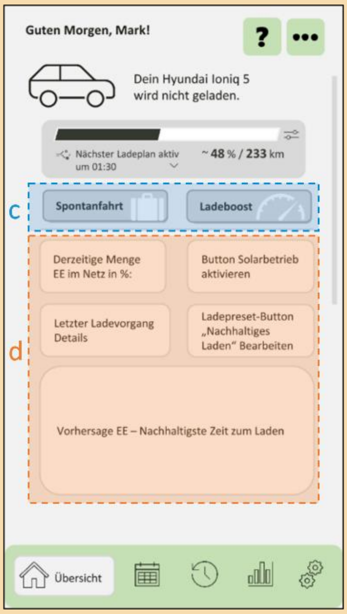
2.4.3. Results

Prototype design

The discussion about the design of the prototype was split across the individual screens of the interface.

Main screen. With regard to the main screen of the prototype, the participants had remarks on four key areas of the interface. Table 7 presents these remarks in detail.

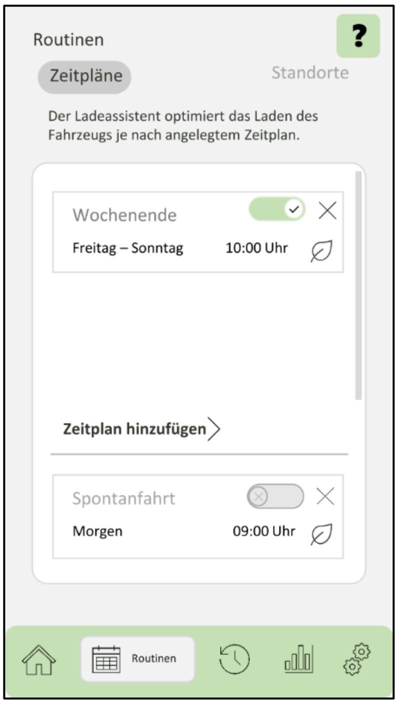
Table 7. Remarks regarding the main screen.

Screen preview	Comments from the participants
	a) - **Display of your own vehicle:** It is important that your own vehicle is displayed in the app both as text and as an image, especially if you have several vehicles. - **Management of multiple vehicles:** Users who own multiple vehicles should be able to switch between these vehicles easily in the app. - **Vehicle information**: The display of whether the vehicle is charging is rated as positive. b) - **Display of the state of charge**: The display of the state of charge in the app was considered unnecessary by some participants, as this information is already available in the vehicle; other participants rated the information as useful, especially as a percentage. - **Transparency**: The information on the next charging schedule was rated positively.
	c) - **Names of the buttons:** The difference between *Charging Boost* and *Spontaneous Trip* should be better defined, as these terms are unclear. Suggestions for alternative names for 'Spontaneous Trip' are 'Single Trip', 'Special Trip' and 'Next Trip'. 'Charging Boost' should be called 'Spontaneous Trip' instead. d) - **Various preferences**: The customisable areas can be used to implement different requirements and needs, with some people considering price information on the main screen to be necessary and desirable. Other people wanted buttons that automatically activate the cheapest charging, the fastest charging or charging with renewable energy (excess PV power).

The focus groups concluded that the dual-part structure of the prototype main screen, comprising a static and a customisable area, ensures optimal flexibility and user-friendliness.

Charging Schedules. Regarding this screen, participants in the focus group discussions gave remarks that we have grouped into four distinct categories. The first category pertains to the design of the screen, the second to the distinction between the utilisation of the app in private and public settings, the third to the necessity for planning and flexibility, and the fourth to the reliability and intelligence of the app. The specific comments can be found in Table 8.

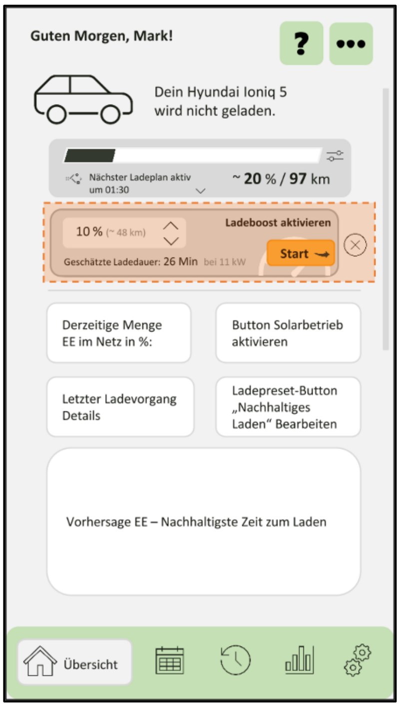
Table 8. Remarks regarding the *Charging Schedules* screen.

Screen preview	Comments from the participants
	Design: - **Importance of multiple departure times**: The ability to set multiple departure times in the app is considered important. - **Departure time & smart charging modes**: The ability to set departure times and smart charging optimisation modes such as green, cheap, and slow charging is highly valued. For some users, sustainability is more important than price. - **Universal settings instead of frequent adjustments**: As the settings are likely to be changed only rarely, they should be as universally adjustable as possible.
	At home vs. public space: - **Difficulties in implementing charging schedules in public spaces**: Charging schedules probably only make sense if the car can be charged at home. Charging schedules are difficult to implement in public spaces due to the unpredictable availability of charging points and blocking fees.
	Planning vs. flexibility: - **Different practicability of fixed charging schedules**: Fixed charging schedules prove to be impractical for some users, as they make spontaneous, irregular journeys and do not (want to) plan their journeys in advance. Fixed schedules are also often not helpful for users with varying daily routines. For other users, however, such as students or professionals, fixed charging schedules would be very useful and practical. - **Infrequent drivers want weekly charging at favourable prices**: Some people drive so little that they do not need to charge frequently (daily). In such cases, it would make more sense to charge the vehicle once a week, for example, when the price is low.
	Reliability & intelligence: - **Ensuring the state of charge by the departure time**: It is important to ensure that the set state of charge is reached by the departure time. - **Intelligent charging function in favourable conditions**: The function of charging more electricity when conditions are favourable is considered intelligent and beneficial. In eco mode, the vehicle should charge more electricity than the originally set target level if a photovoltaic system is available.

In conclusion, participants considered *Charging Schedules* as practical for people with fixed daily routines and regular charging needs. They highlighted benefits, such as the configuration of different schedules that can be quickly activated or deactivated or the individually adjustable optimisation of charging. However, they also identified potential challenges, such as the amount of work that can be involved in setting up charging schedules and the fact that the flexibility of smart charging depends not only on the driver but also on the (public) charging infrastructure**.**

Charging Boost. Regarding the *Charging Boost* screen, participants commented the flexibility of the functions, the user-friendliness of the interface, and the usefulness of the features. Additionally, some participants provided design recommendations. The specific comments can be found in Table 9.

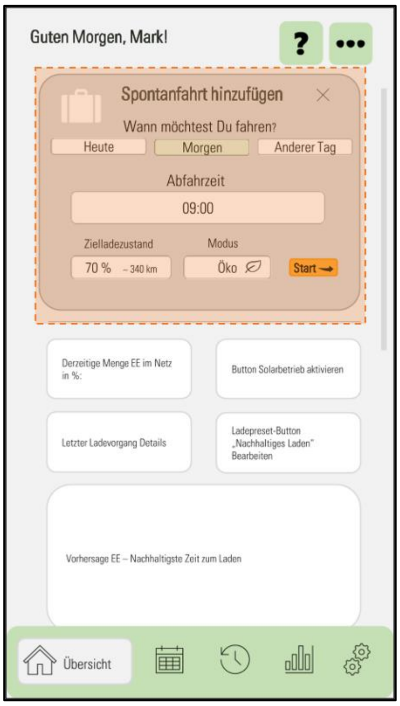
Table 9. Remarks regarding the *Charging Boost* screen.

Screen preview	Comments from the participants
	Flexibility: - **Flexibility and spontaneity:** Participants praise the flexibility and the ability to adjust the charging schedule spontaneously, as this is helpful in many everyday situations. The function is perceived as useful and practical, especially for spontaneous charging situations. The control over the charging process is particularly appreciated.
	User friendliness: - **Desire for ease of use and fast charging options**: Ease of use is emphasised as positive. Some participants would like an even simpler solution ('simply plug in') without having to set the charging amount. - **Integration on the main screen ensures quick access**: The integration of this function on the main screen of the app is rated positively, as it enables quick access. This can be particularly advantageous in stressful situations.
	Usefulness: - **Usefulness and utilisation of the *Charging Boost* in different situations**: Some participants find the *Charging Boost* useful for spontaneous, short-term charging situations, such as long journeys or unexpected earlier departures. Others see the function as a useful emergency option (in addition to the schedules), even if they would not use the limit often. They would want to continue their journey quickly anyway.
	Design recommendations: - **Suggestions for improving the setting of the charging target**: Suggestions include the use of a slider for setting the charging target to simplify operation. The clarity of the display, for example, by using a '+' sign in front of the percentages, is considered important. - **Further design recommendations**: Adding warnings about blocking fees is considered important.

The focus groups agreed that the *Charging Boost* feature is a valuable addition to *Charging Schedules*. However, it's unlikely to be used frequently. But in exceptional situations, it should be quick and easy to access and operate.

Spontaneous Trip. Regarding the *Spontaneous Trip* screen, participants offered comments pertaining to the usefulness and functionality of the features and the design of the prototype. The specific comments can be found in Table 10.

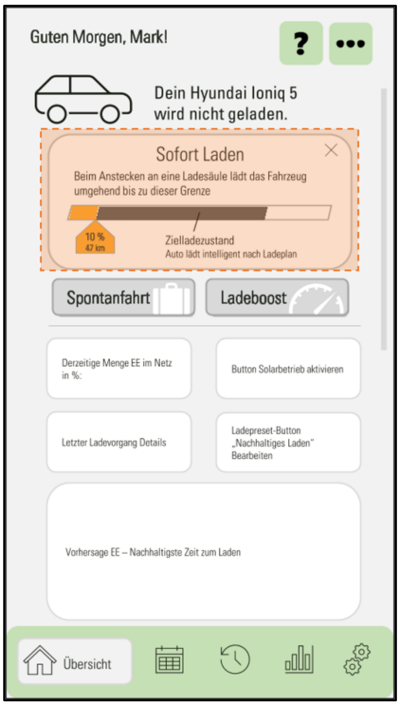
Table 10. Remarks regarding the *Spontaneous Trip* screen.

<table>
<tr><th>Screen preview</th><th>Comments from the participants</th></tr>
<tr><td rowspan="3">
</td><td>Usefulness:
- Need for functions for special charging situations: For special situations, such as longer journeys, it is necessary to charge the car once to 100%. Although spontaneous journeys may be rare in everyday life, a corresponding function should still be available for spontaneous events.</td></tr>
<tr><td>Design:
- Improving the layout: The layout of the app is considered impractical, as the charge level display disappears when the spontaneous journey is used. It is suggested that the spontaneous journey function be placed in the centre of the screen and the charge level display be retained at the top (as with instant charging), as this information is needed to decide on the destination charge level.
- More transparency for more trust: More information on the charging process (as an optional preview) would be helpful, e.g., when the charging process starts and how long it takes.</td></tr>
<tr><td>Functionality:
- Practical choice between different charging modes: The ability to choose between different modes such as eco or economy mode is considered practical.
- Integration with the calendar as a desirable function: The combination with the calendar is seen as desirable in order to better integrate the function.</td></tr>
</table>

The focus group concluded that the *Spontaneous Trip* function is a practical feature that can be used to respond to one-off planned trips Although the frequency of use of this feature varies between participants it is a valuable addition in certain situations. Further improvements could be made with minor design changes.

Instant Charging. Regarding the *Instant Charging* feature, participants offered comments pertaining to the design of the feature, the labelling, and the usefulness of the features. The specific comments can be found in Table 11.

Table 11. Remarks regarding the "Instant Charging" screen.

Screen preview	Comments from the participants
	Design: - **Preference for kilometres**: Some participants prefer to state the remaining range in kilometres rather than percentages. This range should always be available regardless of the weather/season. - **Suggestions for improving the user interface and icons**: A lightning bolt symbol on the start screen would be more intuitive than a slider symbol. The lightning symbol could be visualised as illuminated when instant charging is activated. - **Rare use**: As the function is rarely needed and it is a one-off setting, it should not be placed too prominently in the app. Instead, it could be located in the settings.
	Labelling: - **Suggestion for a clear name**: The function should be called 'Minimum charge', as it is about reaching a minimum charge level.
	Usefulness: - **Controversy**: The 'instant charging' function contradicts the idea of protecting the grid. In addition, the car is rarely driven empty like this in everyday life, as some participants already plan for such an 'emergency reserve' during regular charging. Nevertheless, some participants praised the idea of the function to avoid 'emergencies'.

The focus group's conclusion on the *Instant Charging* feature is that it is practical for drivers who want to quickly charge their car to a minimum range. The function is particularly useful when smart charging is expected to cause a delay**.**

<u>Novel input for app features</u>

Participants were further instructed to generate ideas for new app functions and features, which resulted in ten new suggestions. These are presented in Table 12. Furthermore, participants were instructed to design their ideas using a paper-pencil-approach and draw their design onto a smartphone template. An exemplary drawing is presented in Figure 6 (i.e., the distinction between smart charging content and instant charging content).

Table 12. Overview of the ideas for new features.

Number	Idea
1	**Enable price-dependent charging, but don't just focus on the price:** - The app should make it possible to control the charging process depending on the current electricity price and set a maximum price below which charging takes place. - The app should not only focus on price advantages but should also take ecological and comfort-related aspects into account.
2	**View electricity prices and availability:** - Users should be able to view the costs and availability of charging points in the app so that they can make informed decisions.
3	**Create incentives for smart charging:** - The app should offer incentives, such as cheaper prices, to promote the use of smart charging.
4	**Integration and compatibility**: The app must be able to communicate seamlessly with car apps, wallboxes, and PV systems.
5	**Time and capacity planning:** - Time and capacity planning functions should be available so that users can plan their load times and quantities. Users should be able to set multiple departure times.
6	**Notifications & accurate charging information:** - The app should send notifications when charging is complete or when certain conditions (such as low prices or, available charging points) are met. - Displaying inaccurate or misleading charging information should be avoided, as this may affect user confidence.
7	**Provide ecological information and use surplus PV power:** - The app should enable charging with excess energy from renewable sources, such as photovoltaic systems. It should be shown how high the share of charged electricity is made of renewable energy.
8	**Taking battery health into account:** - The effects of charging on battery health (in terms of longevity) should be considered and optimized.
9	**High usability and avoidance of unnecessary additional apps:** - The app should be simple and easy to use and not introduce unnecessary complexities that could scare users off (e.g. a two-button solution). - The introduction of an additional app should be avoided as long as existing solutions can be integrated to prevent app overload.
10	**Taking public charging requirements and infrastructure into account:** - Public charging requirements and complications should not be ignored (e.g., current infrastructure, blocking fees, etc.). The app should also be useful for users without a private wallbox.

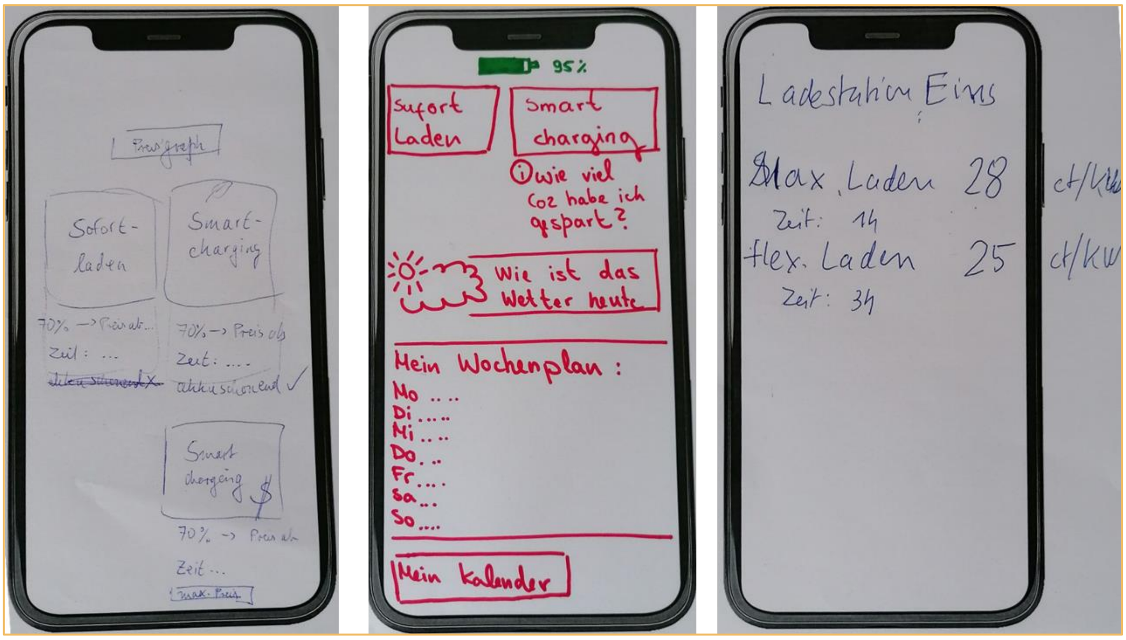


Figure 6. Example of novel app-feature generated by three participants: Comparison of "Smart Charging" and "Instant Charging". *Note*: Instant charging appears on the left side of the display, with details on price and time until the state of charge has been achieved. On the right side, various smart charging options are shown (e.g., cheaper or more battery-friendly charging options).

2.4.4. Conclusion and learnings

Overall, the focus group's assessment of the prototype was positive. In particular, the combination of flexibility and user-friendliness of the main screen through static and customisable areas was appreciated by the participants. *Charging Schedules* were found to be useful for regular daily routines, while the *Charging Boost*, *Spontaneous Trip* and *Instant Charging* functions were more likely to be used in exceptional situations. The frequency of use of these functions depends heavily on the individual situation and can vary interindividually. New ideas for features included the integration of additional information (weather, price, charging options, etc.) and the desire for support with personalised charging planning (e.g. through recommendations, calendar integration, etc.). The focus groups generated valuable input for the improvement of the prototypical smart charging app. Compared to the user studies, we were able to delve deeper into the participants' thoughts and opinions, facilitating a richer understanding of their experiences and expectations. The focus group discussions allowed for a more nuanced exploration of specific issues and potential solutions. Additionally, the interactive nature of focus groups helped uncover latent needs and preferences that might not have been identified through individual user studies alone. This qualitative approach enriched our comprehension of user behaviours and attitudes, offering actionable insights that are crucial for refining and enhancing the app's functionalities.

Ultimately, ten key learnings can be derived from the results of the focus group discussion.

1. **Minimalist design**: The app should be easy to use, especially for less tech-savvy or older people.
2. **Clarity and controllability of the charging options**: A user-friendly presentation of charging options is important. The controllability of fast charging should be improved, especially in public areas.
3. **Price cap for charging**: Introduction of a price cap for charging to benefit from favourable electricity prices. The app should start the charging process automatically when prices are favourable.
4. **Traffic light system for charging requirements**: Visualisation of charging times and requirements through a traffic light system with clear colour codes.
5. **Integration of weather forecasts**: Using weather forecasts to better plan charging times, taking into account the reliability and accuracy of forecasts.
6. **Route planning with charging requirement analysis**: Integration of route planning, which analyses charging requirements.
7. **Taking battery temperature into account**: Taking battery temperature into account when planning charging, especially in cold weather.
8. **Forecast of electricity prices and charging recommendations**: Integration of a function for forecasting electricity prices and recommendations for the optimal state of charge to optimize costs and be environmentally friendly.
9. **Calendar integration for personalised charging schedules**: Automated charging schedules based on the user's calendar to increase convenience.
10. **Management of multiple users and vehicles**: Support for multiple user profiles and vehicles for flexible administration and planning in households or companies.

In addition, on several occasions, participants expressed concern that the features of the app would only be implemented for private charging but would also be of interest for public charging. Thus, the entire app, with all its functions should also be suitable for **public charging**. This requires the availability of smart charging at public charging stations and coordinated communication between all parties involved.

Our approach comes with a few limitations including that participants were mainly men with an affinity for technology. This could limit the generalization of the results to other individuals. In addition, not all participants had experience with charging at home.

2.5. Summary & recommendations for all testbeds and demonstration sites

During the course of the project, we conducted several studies to identify user requirements that must be met to ensure user satisfaction with smart charging.

Essentially, two basic requirements need to be met:

(1) Users need a basic understanding of smart charging and access to a variety of information.
(2) Users need to be able to monitor and control their own charging processes.

Addressing the first point, the **general recommendations for setting up demos and testbeds** are:

- Inform and educate users about smart charging (even if it is being tested in the background).
- Support the users.

As charging apps offer the opportunity to provide specific user-related information and feedback and also address the second point, we focused on smart charging apps.

Based on desk research, prototyping, and evaluation studies, we were able to derive recommendations for a user-centred charging app that meets these requirements.

Recommendations for **app design and information presentation**:

Minimalist design. The app should be easy to use, especially for less tech-savvy or older people.

Create clarity in complexity by a clear and organized layout. This includes prominently displaying the charging bar and essential information, such as the next charging schedule, on the home screen. It is crucial to use clear function labels and intuitive symbols.

Provide transparency.

- Clearly **visualise when the vehicle is expected to charge and when the charging process is anticipated to be completed, or at the latest, finished**. Additionally, there should be a clear and concise visualisation of charging goals (e.g., immediate charging goal, smart charging goal) and the set schedules (routines and exceptions).
- The visualisation of charging times and requirements could be implemented through a **traffic light system** with clear colour codes.
- **Present a variety of data related to charging history and statistics,** placing them in close proximity within the menu structure. The statistics diagrams should be clear and not overloaded with information, and the charging history should be straightforward, with the option to access additional details via a submenu if necessary.
- **Integrate weather forecasts** to better plan charging times, taking into account the reliability and accuracy of forecasts.

Integrate forecasting of electricity prices and recommendations for the optimal state of charge to optimise costs and be environmentally friendly.

Recommendations for **app features:**

Give users control and autonomy and allow personalisation.

- **Accommodate flexible charging schedules and targets,** allowing for daily routines and exceptions, as well as various charging goals such as immediate charge limits for quickly restoring a minimum state of charge (SoC).
- **Introduce a price cap** for charging to benefit from favourable electricity prices. The app should start the charging process automatically when prices are favourable. Traffic light system for charging requirements: Visualisation of charging times and requirements using a traffic light system with clear colour codes.
- **Integrate route planning**, which analyses charging requirements.
- **Take battery temperature into account** when planning charging, especially in cold weather.
- Integrate a function for **forecasting electricity prices and recommendations for the optimal state of charge** to optimise costs and be environmentally friendly.

Integrate a calendar for personalised charging schedules: Automated charging schedules based on the user's calendar to increase convenience.

Recommendations for a **one-fits-all-solution:**

Make the entire app with all its functions suitable for **public charging.**

Integrate all vehicle functions (beyond smart charging functions) into a single app.

Enable connections with other apps and data sources, such as weather forecasts and price predictions (if not integrated in the app itself).

It is evident that the general recommendations also need to be applicable to public charging apps. Subsequently, the following chapters provide detailed recommendations for the design of smart charging apps for public charging scenarios, with reference to use cases in Copenhagen, Dublin and Menorca.

3. Improving users' smart charging intention in Menorca through information presentation and HMI-design

3.1. Aim

Our previous user research has identified various determinants for users' intention to use smart charging (e.g., privacy concerns, trust in involved actors, BEV experience, usability improvements). The aim of the following study was to investigate whether the willingness to participate in smart charging practices and the acceptance of smart charging can be promoted by providing appropriate information to the user. The special focus of this setup were users with no smart charging experience, indicating first-time users with a clear need for information. To this end, different information presentation formats that are easy to implement in smart charging apps were developed and empirically tested.

In order to show users the potential of smart charging and consequently motivate them to use it, it is first necessary to communicate the modern technology and its advantages in an understandable way. According to Mayer (2002), the learning of new information can be (simplified) understood as the interaction between newly acquired and existing information (Haas, 2015). In order to achieve an optimum learning or elaboration performance, information should be presented in such a way that background knowledge can be activated and linked to new information (Wirth, 1997). To present information, informative texts and diagrams (Alexander, 2013), storytelling (Braun, 2001), and statistics (Larkin & Simon, 1987) were previously proven to be useful strategies.

Informative texts are the simplest way of presenting bundled information. In combination with visual representations, such as figures or graphics, information can be better absorbed and remains longer in the memory (Luck & Vogel, 1997). Storytelling can be understood as a form of constructing a narrative level of public communication (Szyszka, 2008). According to Clark and Rossiter (2008), storytelling improves the information transfer. With the help of a text-based narrative, empathy is experienced, and the concept is conveyed in an exemplary and visual way (McDowell, 2021). It is therefore particularly suitable for realistic and concrete scenarios (Landrum et al., 2019). According to Larkin and Simon (1987), the use of diagrams and statistics enables an efficient way of perceiving complex information, as the relationships can be linked with just a few glances. Carlson et al. (2003) found that retention performance improves with increasing complexity of information when this is supported by diagrams. According to Heintz (2021), statistics can also stimulate the competitive spirit of users by enabling a direct comparison of performance and thus serve as an element of gamification. In this context, Beck et al. (2019) found that energy-related apps with elements of gamification received better user ratings.

To deepen the understanding of best practices for information presentation in apps, to promote users' intention to choose smart charging, three formats of information presentation are tested. Thus, within this study the potential of informative text and figures, storytelling, and statistic to increase users' willingness to use smart charging were investigated.

3.2. Methodology

3.2.1. Study design

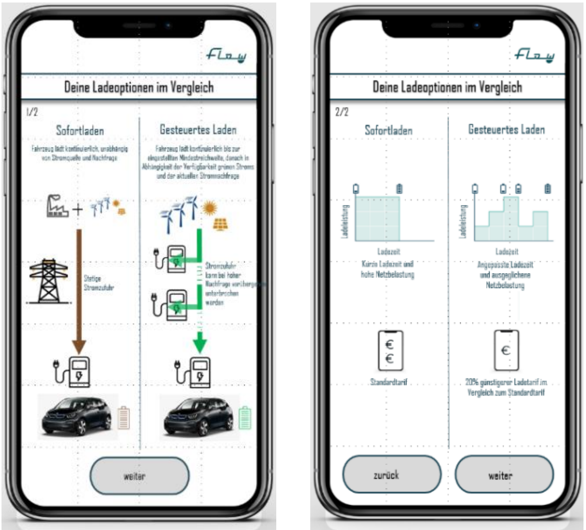
In this study, a 3 x 2 experimental cross-sectional design was used to determine the influence of the different forms of information presentation on the users' intention to choose smart charging. The information presentation comprised three conditions and differed in only the presentation of informative texts and figures (the condition is referred to as *information* in the following, the addition of storytelling (the condition is referred to as *information+storytelling* in the following), and the combined presentation of information and statistics (the condition is referred to as *information+statistic* in the following). The prototype is presented in Figure 7 to Figure 9. The testing was carried out in a between-subjects design, as each person was assigned to exactly one condition. The user' intention to choose smart charging was assessed before (Pre) and after (Post) the interaction with the app. Participants' intention to choose smart charging was assessed with a two item 6-point Likert scale ranging from 1 *completely disagree* to 6 *completely agree*.

Start screen and welcome (identical for all groups)

The user is welcome with information on the vehicle's condition (SOC and range) and the option to find out more about smart charging.

Figure 7. The tested prototype: start screens.

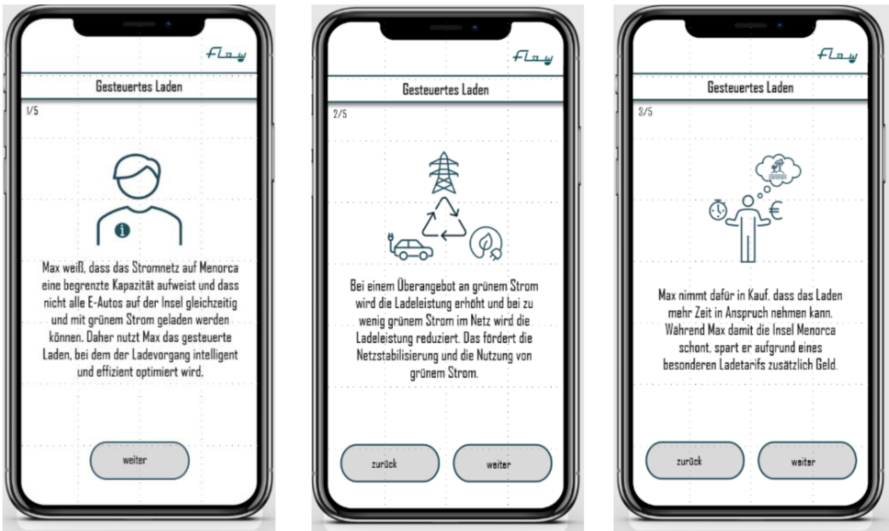
Screens for the *information* condition



Comparison of instant charging and smart charging based on energy source, charging process, charging duration, and charging price.

A *back* and *next* button allow the user to navigate.

Screens for the *storytelling* condition



Presentation of a fictitious EV user in Menorca who is aware of the bottlenecks in the electricity grid and compares the advantages with the disadvantages when deciding in favour of smart charging.

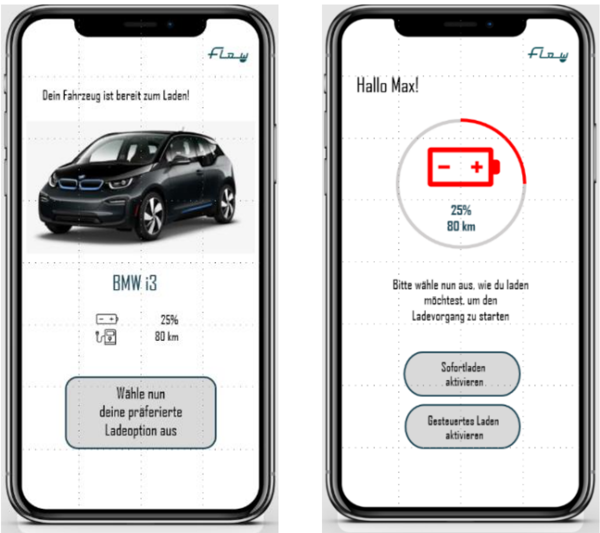
Screens for the *statistic* condition

Presentation of statistics that include all charging processes and the proportion of smart charging at Menorca. It shows the associated costs and CO2 savings as well as the utilisation of green electricity based on smart charging.

Presentation of an individual ranking with regard to cost, green energy, and CO2-emissions based on the statistics compared to all other users at Menorca.

Figure 8. The tested prototype: the three conditions *information, storytelling,* and *statistics.*

Final screens (identical for all groups)



Again, information on the vehicle's condition (SOC and range). As the EV is ready to charge, the user is requested to choose between immediate and smart charging.

Figure 9. The tested prototype: final screens.

3.2.2. Participants

The laboratory study comprised a total sample of *N* = 91 participants, who were recruited both by email via the Chemnitz University of Technology study mailing list and through private distribution. The allocation of participants to one of the three conditions was randomised. As a result, 30 people each tested the prototype of the *information* and the *information+storytelling* condition, and 31 tested the prototype of the *information*+statistic condition.

The average age of all participants was 22.5 years (*SD* = 5.5, *Min* = 18 years, *Max* = 60 years). 27 people (30%) self-identified as male, 63 people (70%) self-identified as female, and one person (1%) stated that their gender identity was diverse. In terms of education attainment, 76 participants (84%) stated that they had a high school diploma and 15 (16%) a university or college degree; no other qualifications were mentioned. The groups did not differ in terms of demographic variables.

3.3. Results

Participants' intention to choose smart charging significantly increased through the interaction with the developed prototype ($F(1,88) = 60.17$, $p < .001$, $eta^2_p = .41$). There were no significant differences in participants' intention to choose smart charging between the three conditions after dealing with the developed prototype ($F(1,2) = 2.79$, $p = .067$, $eta^2_p = .06$). Nevertheless, the strongest improvement could be observed in the *information+statistic* condition, followed by the *information+storytelling* condition. Figure 10 displays the results and revealed that all conditions were useful presentation strategies and led to a strong increase in participants' smart charging usage intention.

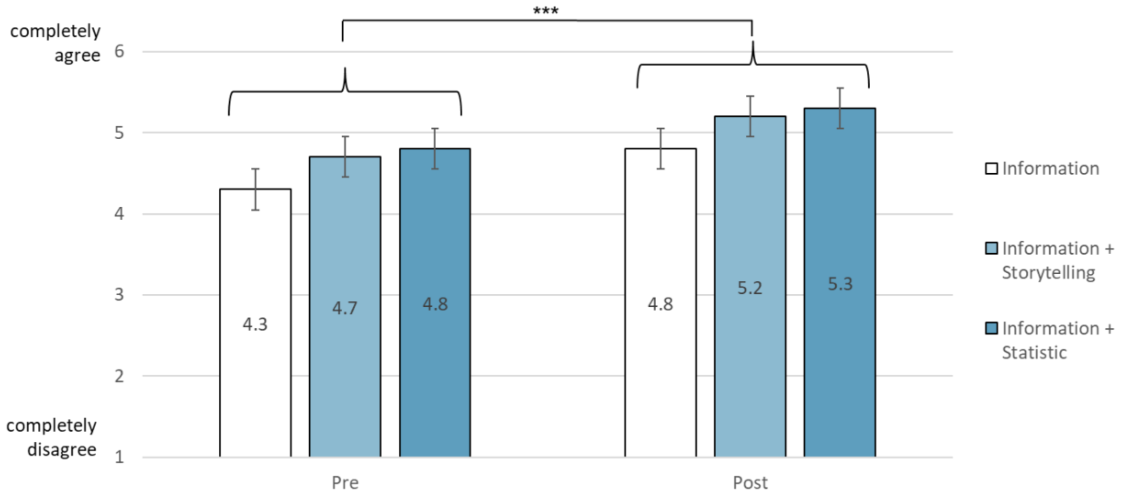


Figure 10. The influence of presentation format on participants' intention to choose smart charging before (Pre) and after (Post) dealing with the developed prototype. *Note.* $N = 91$; $n_{information} = 30$, $n_{information+storytelling} = 30$, $n_{information+statistic} = 31$. ***$p < .001$.

3.4. Summary and recommendations for information presentation and HMI-design in the Menorca setting

This study was able to demonstrate that participants' intention to use smart charging in the Menorca setting can be significantly increased by an appropriate HMI design with information processing tailored to the user. The formats of presentation tested (information, storytelling, and statistics) are equally useful. The simplest presentation is associated with the presentation of informative texts and illustrations (*information* condition). More complex forms, such as the integration of statistics and gamified elements, are associated with more demanding programming efforts and data processing processes, but also appear to contribute to a trend towards a greater increase in the intention to use smart charging.

However, it must be mentioned as a limitation of the present study that the study participants predominantly had no previous BEV experience and were interacting with a smart charging prototype for the first time. The effects on long-term behavioural motivation cannot be quantified in this study.

Nevertheless, based on our findings the following recommendations for the design of smart charging applications to motivate users´ engagement in smart charging practices can be derived:

(1) Provide meaningful information regarding the benefits of smart charging compared to conventional charging.
(2) Use a wording that is easy to understand for users (non-technicians or experts).
(3) Include feedback regarding individual charging and energy consumption behaviour.
(4) Add gamification elements, such as rankings, scores, and leader boards for the comparison with other users.

4. Enabling smart charging in Copenhagen with the Spirii Go App

4.1. Aim

The demo site Greater Copenhagen aims at harmonising smart charging and V2G across a number of hubs representing different charging settings and topologies and ultimately promoting harmonisation across Europe while focussing on user-centred design. Spirii (SPI) already operates a smart charging app solution for both public and private charging in Denmark with roaming options to charge all over Europe, called Spirii Go. To evaluate Spirii Go's usability, a laboratory user study was conducted. Additionally, Spirii Go's current set of smart charging features was assessed to evaluate the app in terms of the requirements for the demo site Greater Copenhagen. The results formed the basis for the development of recommendations on how to integrate further smart charging options easily into Spirii Go and thus foster the use of smart charging in a wide range of contexts (private, semi-public, and public) and locations (rural and urban). While doing so, special attention was paid to public charging, which has often been neglected so far.

4.2. Assessing the usability of a smart charging app

To assess users' opinions on the smart charging app Spirii Go, a laboratory study was conducted. The main focus was on the evaluation of the app's usability. In addition, user satisfaction and visual aesthetics were examined.

4.2.1. Methodology

Participants

The user study was conducted from January to May 2024 with students at TUC. The final sample resulted in $N = 65$ participants, with $n = 44$ identifying as female and one person identifying as diverse. Participants were between 18 and 38 years old ($M = 22.46$, $SD = 3.65$). Two participants had a university degree, while $n = 63$ had completed their A-levels.

Study design and procedure

The study was conducted at facilities of TUC. Most participants took about 20 min ($M = 19.76$, $SD = 4.83$, $n = 65$). After they gave informed consent, participants were handed a smartphone, on which they solved several EV charging related tasks with the app Spirii Go (Version 3.7.2). The tasks were embedded in a scenario describing EV charging events in a leisure context. With this scenario in mind, participants were given twelve tasks grouped into three blocks. Tasks of the first block provided participants with an overall view of the app. Tasks of the second and third blocks illustrated how to use the app to look for, select, or navigate to a charging point and how to initiate a charging session. A short description of the single tasks is presented in Figure 11.

While the participants solved the tasks, the experimenter rated their task performance (Forster, 2020) and recorded any comments that participants made regarding the app's design, functions or usability.

Participants then evaluated the app's usability by completing the SUS (Brooke, 1996) and the SmartUse (Mohr et al., 2024). The SmartUse (Mohr et al., 2024) is a short scale to evaluates the perceived usability of mobile apps with two subscales, *Clarity of Design* and *Ease of Interaction*. Its 10 items reflect a selection of design features that are particularly important for mobile app usability. A more comprehensive list of mobile app usability design features can be found in Huang & Benyoucef (2023). In addition, participants indicated their satisfaction with the app via the USE's Satisfaction subscale (Lund, 2001) and the app's visual aesthetics via the short version of the Visual Aesthetics of Websites Inventory (VisAWI-S, Thielsch & Moshagen, 2011). A cognitive load scale (Klepsch, 2020) was employed to assess participants' mental effort associated with task difficulty (intrinsic) and information presentation, e.g., app design (extraneous). Both the scales and their items were presented in a randomised order. Lastly, participants provided some personal information.

4.2.2. Results

<u>Experimenter ratings and comments</u>

Figure 11 illustrates participants' mean task performance as rated by the experimenter (Forster, 2020) as well as a short description of the different tasks. During the study conduct, some issues arose that resulted in different sample sizes for the single tasks. This included:

- **charge point interfaces and/or profile menu interface not load properly**, therefore tasks not being workable
- task 11 (changing notification settings) was separated from task 10 (charging initiation) after the first nine participants as the performance of the two subtasks vastly differed

In general, participants' performance matched the anticipated task difficulties. Beyond that, the following challenges and issues arose and were noted by the participants:

- charging history was hard to find and was not placed intuitively
- notification settings were hard to find. Participants expected a link to the notifications on the charge point interface
- icon for profile menu lead to confusion since the profile menu encompassed not only profile settings but also settings that were expect in a main menu
- menu to enter car details was hard to find
- not saving the car details after entering
- the app's colour scheme was perceived as desaturated
- full costs for charging at public charging station not found as participants thought the price on the overview pop up of charge points indicated the full charging costs
- possibility of switching between light mode and dark mode was wanted

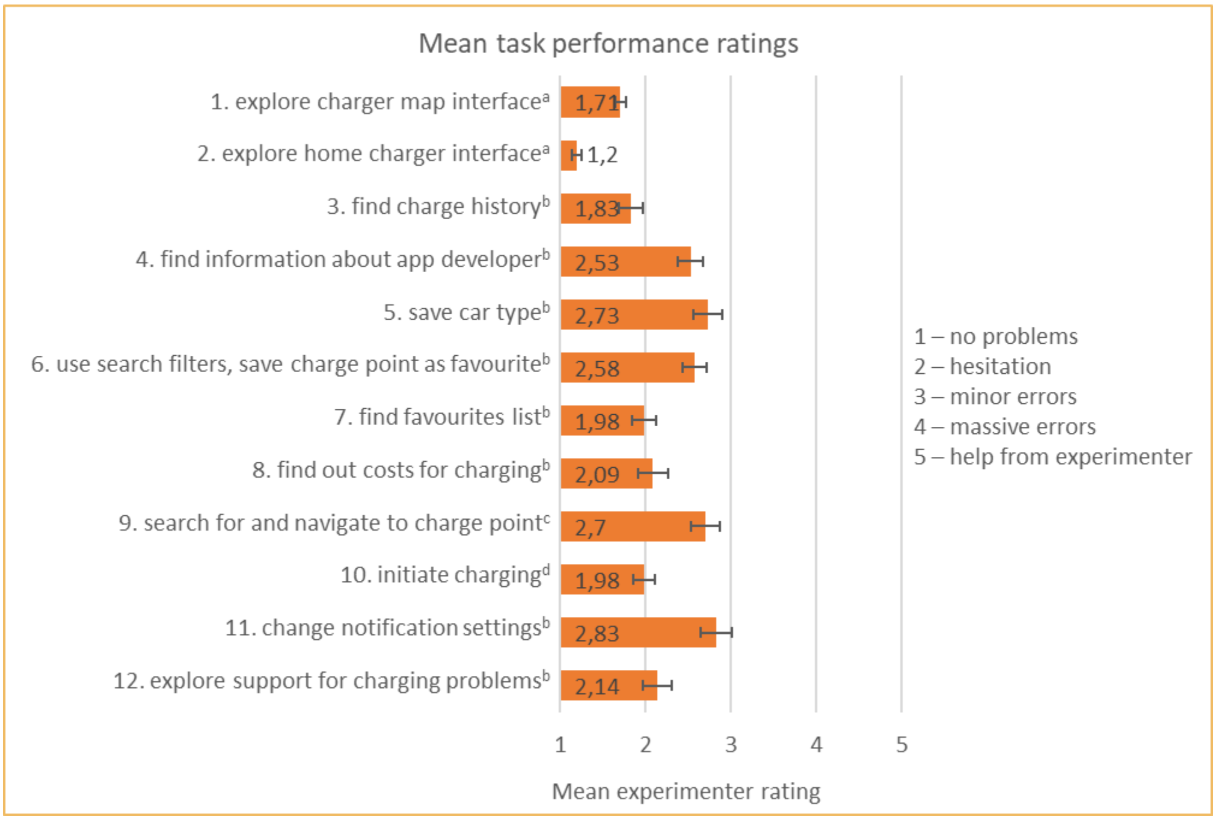


Figure 11. Mean experimenter ratings (Forster, 2020) for the different tasks. *Note:* Numbers indicate mean. Error bars indicate standard error of means. [a]*n* = 65, [b]*n* = 64, [c]*n* = 63, [d]*n* = 55.

<u>User evaluation</u>

Table 13 shows the scale's descriptive statistics. Spirii Go obtained a good and above-average usability rating. The SUS score is corresponding with grade B on the curved grading scale developed by Sauro & Lewis (2016) and the SmartUse subscales scored well above the scale's centre. Inspecting the individual items, items with the highest mean scores referred to the app as being easy to learn and useful. However, there seemed to be potential for improvement. For example, SmartUse items with the lowest mean scores assess whether a display can be viewed at a glance, control elements in the app are well defined or the app's menu navigation is clear. VisAWI-S and the USE Satisfaction subscale obtained scores well above their scale's centre, indicating that participants perceived Spirii Go's visual aesthetics as good and were satisfied with the app. Looking closer into the individual items of the scales, items with the highest means referred to the app as being pleasant to use and professionally designed. Merely the attractiveness of the colour composition was perceived rather poorly. In addition, participants indicated a low intention to use the app in the future, which might be attributed to the fact that participants were mostly students who did not own or use an EV on a regular basis. Nevertheless, participants were quite willing to recommend the app to a friend, which again indicated their satisfaction with Spirii Go. Participants' intrinsic and extraneous cognitive load averaged below their scale's centre, indicating that solving the tasks and working with the app were perceived as easy.

Table 13. Means and standard derivations of the user ratings in the laboratory study.

Scale	mean	sd	rating scale
SUS	74.04	16.33	0-100
VisAWI-S	5.17	2.50	1-7
USE Satisfaction	4.87	1.27	1-7
intrinsic Cognitive Load	2.50	0.94	1-7
extraneous Cognitive Load	2.81	1.14	1-7

4.3. Assessment of smart charging options and starting points for further improvement

The demo Greater Copenhagen requires an app that is user-friendly and enables EV users to use smart charging in a number of contexts (public, semi-public, and private) and locations (urban and rural). As a partner of the Hubject charging network[1], SPI promotes interoperability between different OEMs and CPOs all across the world. Users can harness Hubject's charging network through SPI's app Spirii Go. Thus, Spirii Go is a suitable app choice for further promoting harmonisation and interoperability of EV public (and semi-public) charging in different locations across Denmark and Europe. However, the app's accessibility to private charging and smart charging was limited. Only a few of its features could be categorised as smart charging features as defined in D2.3, and most of them were only accessible when using a home charger. Additionally, the app only supported SPI home chargers that, in turn, were only available in Denmark. Thus, accessibility of private charging and smart charging needs to be expanded to meet the requirements of the demo Greater Copenhagen.

Smart charging features available to Spirii Go users from all countries comprised charging history and statistics features where previous charges were logged and summarised by charging time and location. Furthermore, in some European countries, such as Denmark, Germany, or Spain, Spirii Go offered live statistics on the composition of the current energy mix and its and CO_2 emissions (measured in gCO_2), as well as CO_2 emission forecasts for the next 24 hours.

When charging at home, users of SPI home chargers in Denmark, in addition, were able to set the maximum current during charging and define a timeframe where charging would be optimised by price or CO_2 emissions. To assist users in finding the best time to charge, Spirii Go offered live statistics and forecasts for energy mix CO_2 emissions and mean energy pricing. Beyond that, owners of SPI home chargers were able to publicly share their charger and thus make some extra money and contribute to the expansion of the charging network. Operators of public or semi-public SPI chargers were able to set timed pricing schemes for their chargers to incentivise users to charge at times of the day where prices are low. However, so far only a few operators utilise this feature.

[1] https://www.spirii.com/en/press-releases/spirii-and-hubject-in-global-collaboration-to-provide-plug-charge-solution

4.4. Summary and recommendations for enabling smart charging in Copenhagen with the Spirii Go App

To assess already available smart charging apps that can be utilised at the demo site greater Copenhagen, the app Spirii Go was examined. A user study was conducted that focussed on Spirii Go's perceived usability. In addition, an assessment of Spirii Go's smart charging potential was conducted. The results show that users found Spirii Go quite usable and were satisfied with its functions and appearance. They perceived the app as easy to learn and pleasant to use. Spirii Go's design appeared professional. However, users also indicated room for improvements in terms of usability. Most of the usability issues mentioned by users are reflected in or can be solved following the recommendations for all test beds and demo sites (see 2.5).

Therefore, to enhance usability, Spirii Go needs to follow the recommendations for all test beds and demo sites, in particular:

(1) Expand Spirii Go's charging schedule feature to allow several charging schedules at once for increased usability.
(2) Implement settings for price limits and SOC limits.
(3) Utilise price and CO_2 emission forecasts to specify charging schedule recommendations and estimations of the time the target SOC would be reached.
(4) Integrate weather forecasts and the priority utilization of surplus energy generated by private solar systems.
(5) Include charging statistics about monetary or CO_2 emission savings.
(6) Integrate an option to connect ones car with Spirii Go to increase the app's usability and attraction.

Furthermore, the following recommendations derive from the participants' challenges with task completion and usability evaluation:

(7) Enable a faster and easier access to important functions such as the charging history, e.g. by placing it more prominently in the main menu.
(8) Make sure that the app functions error-free.
(9) Create shortcuts between related functions, e.g. by linking the notifications menu on the charge point interface or linking the car settings on the search filter interface.
(10) Provide a clear menu navigation.
(11) Make displays viewable at a glance.
(12) Make control elements easy to identify.
(13) Use intuitive icons for main menu items.
(14) Prevent user errors, e.g. by using auto save features.
(15) Be transparent about charging costs. Make sure users do not have to search for the information on the full charging costs.
(16) Enable switching between light mode and dark mode.

Regarding smart charging features, Spirii Go partially met the requirements for the demo site Greater Copenhagen. As SPI is a partner of the Hubject charging network, Spirii Go is a suitable app choice for further promoting harmonization and interoperability of EV public (and semi-public) charging across Denmark and Europe. However, Spirii Go only supported smart charging and home charging via SPI chargers in Denmark.

Therefore, to be able to promote the harmonisation and interoperability of smart charging across Denmark or Europe, Spirii Go needs to:

(17) Enable the usage of smart charging features regardless of the charging setting or OEM.
(18) Implement support for home chargers of other OEMs.

All in all, users were satisfied with Spirii Go's usability. Especially, its clear and simple structure made the app easy to learn and use. However, it was apparent, that the German app version was still under development. Spirii Go's smart charging feature set partially met the requirements for the demo site Greater Copenhagen and can be seen as a good starting point for further enhancements. For example, the option to publicly share a private charger not only distinguishes Spirii Go from other smart charging apps on the market but also offers an interesting opportunity for expanding the charging network, especially in rural regions.

5. User requirements for an information platform for smart charging in Dublin

5.1. Aim

Previous studies focused on developing recommendations for the deployment of smart charging systems and smart charging apps. In Dublin, however, the challenge seems to be to enable charging for all, despite the limited availability of charging points. Thus, the aim of the user requirement analysis in Dublin was to identify specific requirements for a tool that would improve the availability of charging and parking facilities on the Maynooth and UCD campuses. Therefore, we asked three research questions:

RQ1. What is the current usage situation from the users' perspective?
RQ2. What interventions would be useful to improve the situation?
RQ3. What are user requirements on an information/communication platform?

5.2. Methodology

To assess user requirements on the Dublin charging infrastructure, face-to-face interviews at both campuses were combined with an observational study at each EV car park. The data collection was conducted from April 19 to 28, 2023, in cooperation between Maynooth University and Chemnitz University of Technology.

5.2.1. Study design and procedure

The study was composed of interviews and observations at the car parks at the Maynooth campus and UCD campus. The interviews consisted of three main blocks of questions (Figure 12). The first block addressed the participants' charging behaviour and their use of the charging infrastructure, focussing on the availability of charging stations at the respective campus. The second block dealt with potential strategies for improving the availability of charging stations. In the third block, the idea of a communication platform was introduced to the participants. Participants were asked about their attitudes toward this system as well as how and what information this system should provide.

At the beginning of each interview, the interviewer briefly introduced himself and explained the objectives of the study. This was followed by a data protection briefing. If the respondent consented to the interview, the recording was started, and the interviewee was asked about the topics described above and in Figure 12. Finally, participants were asked for personal information.

In addition to the interviews, each car park was observed for one day. The observer logged times when a vehicle was at a charging station and assigned them to one of the categories: *Charging* (EV plugged in and charging), *Ready* (EV plugged in and charging completed), *Parking* (car or EV blocking the charger without being plugged in) or *Unknown* (EV plugged in, but unknown charging status due to missing or non-functioning charging station display). The observer also prepared detailed site documentation, including the number and type of charging points and photographic records.

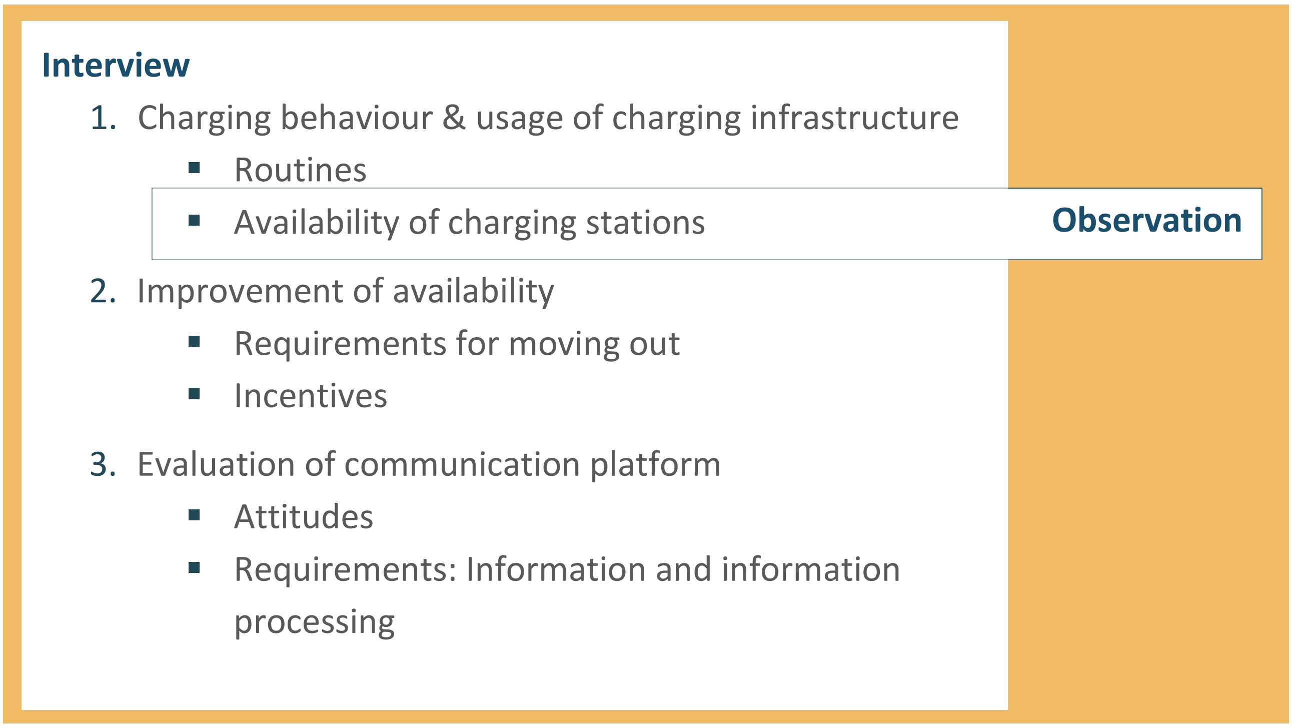


Figure 12. Study design.

5.2.2. Participants

Participants were the users of the EV charging infrastructure at Maynooth campus and UCD campus. The interviewers observed the EV car parks and asked users for an interview. The final sample resulted in N = 20 participants, with n = 10 participants at each campus. Most of the participants were males, 50 years of age or older, and had a university degree (Figure 13). Participants reported very heterogeneous experiences with EVs ranging from one day until 7 years ($M_{years\ of\ EV\ usage}$ = 2.40; SD = 2.00).

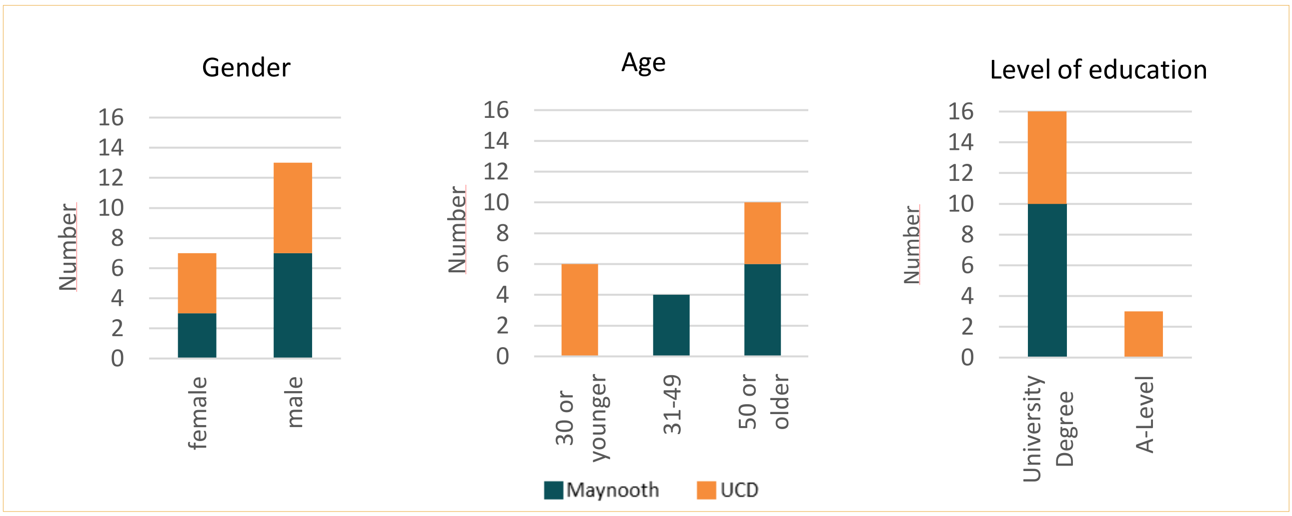


Figure 13. Interview participants at Maynooth campus and UCD campus

5.2.3. Study site

At the time of study execution, there were two EV charging parks at the Maynooth campus: *Campus North*, containing six chargers, and *Campus South*, containing two chargers. At the UCD campus, four EV charging parks were located: UCD1, UCD2, UCD3 with two chargers each, and UCD4 with 24 rather slow chargers. Table 14 summarises the number, type, and charging power of the charging points at both campuses.

Table 14. Specification of chargers at the Maynooth and the UCD campus.

Location	Type	Charging power	Number of chargers
Maynooth North	Type2	22kw	4
Maynooth North	Type1	7,2kw	2
Maynooth South	Type2	7,2kw	2
UCD 1	Type2	22kw	2
UCD 2	Type2	22kw	2
UCD 3	Type2	22kw	2
UCD 4	Type2	2kw	24

5.3. Results

5.3.1. Charging behaviour and usage of charging infrastructure

As shown in Figure 14, most EV users at Maynooth campus (n = 5) reported using a charging point *once a week*. Users of the charging points at UCD campus reported a higher usage frequency: Most of them charged their EVs *almost every day* (n = 3) or *several times a week* (n = 3). Whereas at the UCD campus, charging time and standing time of most EVs (n = 8) at the charging points were both *more than 4 hours;* at the Maynooth campus, most EVs (n = 7) were charged *2 to 4 hours,* but some remained standing at the charging points. Resulting in six EVs blocking the charging points for *more than 4 hours*, even if only three EVs actually charged for *more than 4 hours*.

As charging was free at both the Maynooth and UCD campuses and charging times at both locations could vary considerably depending on the charging point, participants were asked to rate the importance of the factors *charging price*, *charging time,* and *availability* of charging stations for charging their EVs at the campus on a scale from 1 *least important* to 5 *very important*. At Maynooth campus, only *availability* was of higher importance, and significantly more important than *charging price* and *time*. At the UCD campus, all factors – *charging price*, *time,* and *availability* – were important. There were no differences between the factors. Figure 15 illustrates the ratings of the factors at both campuses.

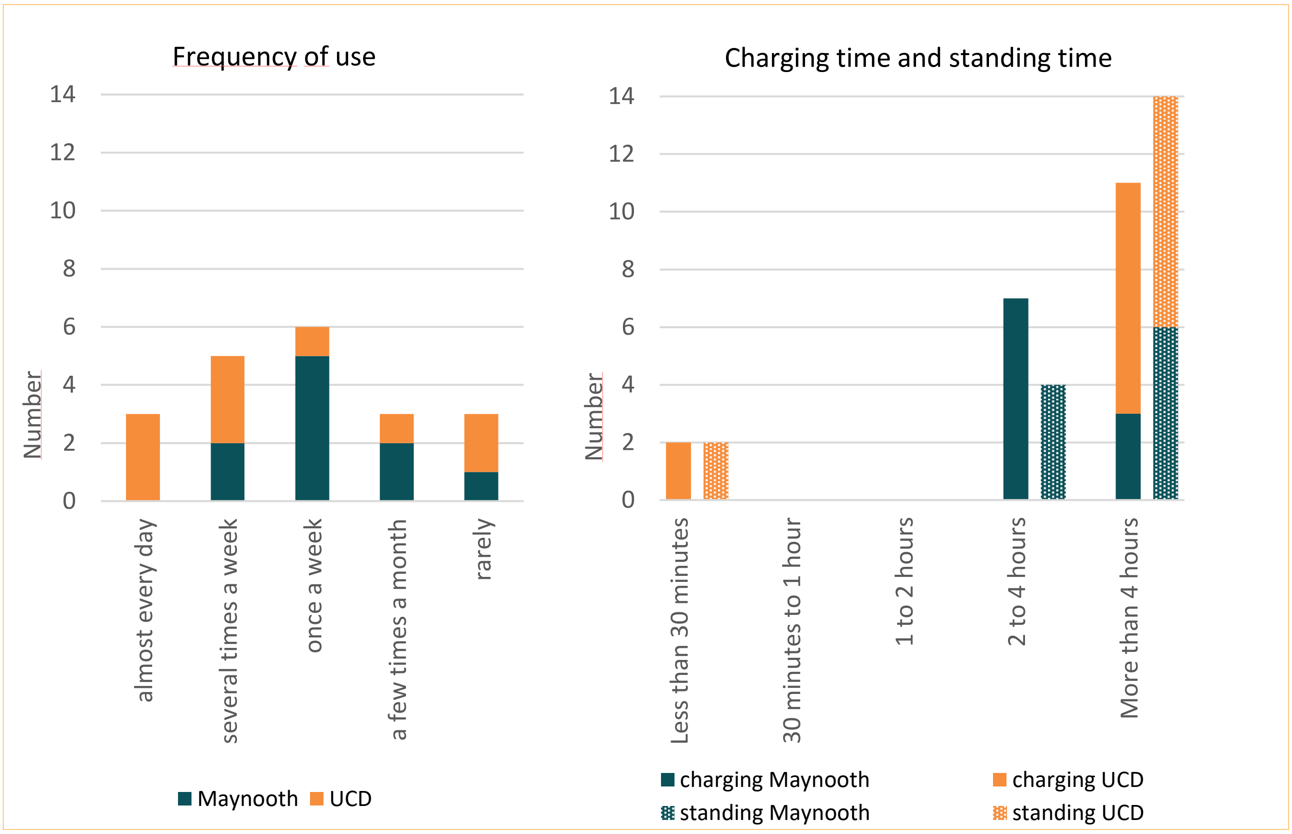


Figure 14. Charging station usage.

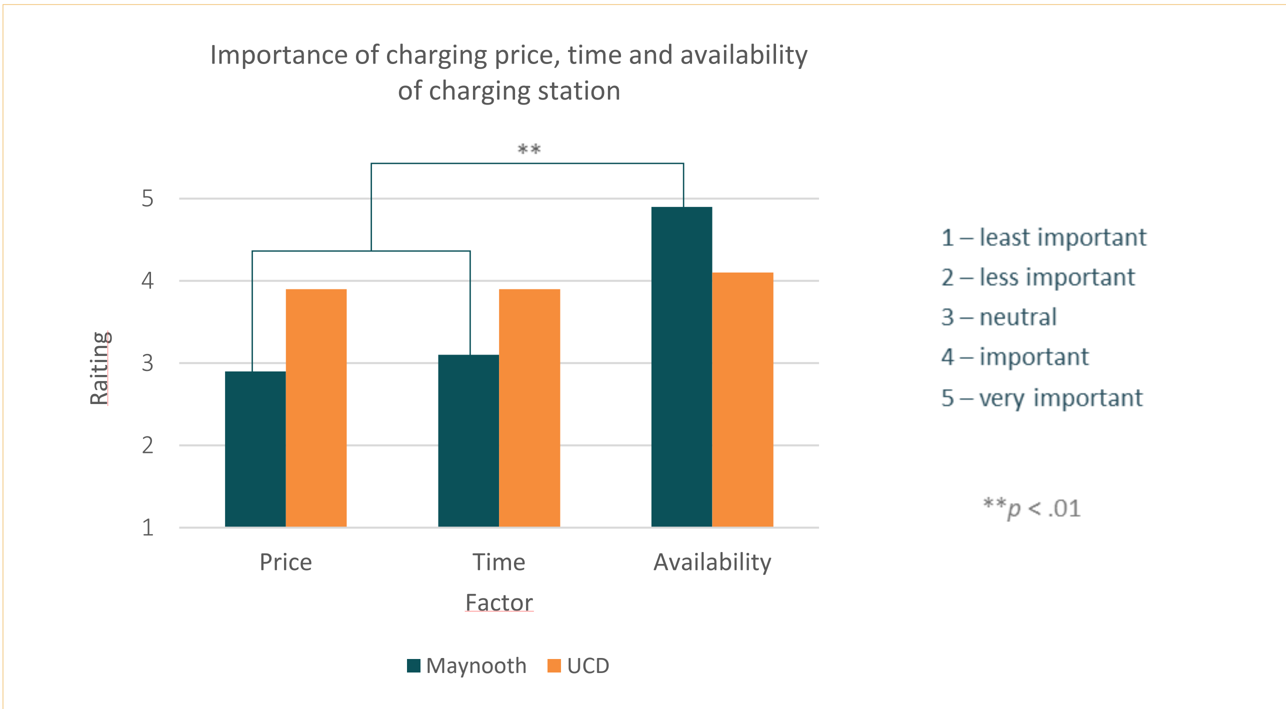


Figure 15. Importance ratings of the factors *charging price*, *charging time,* and *availability* of charging station

That *availability* might be a crucial factor for usage of the charging stations was also shown in the observation study. At the peak times, available charging points were rare – at least at the Maynooth campus. Figure 16 shows the number of available chargers at peak times between 10 and 16 o'clock on April 28 on the UCD campus and the averaged numbers of available chargers between 11 and 15 o'clock of the two days April 19 and 20 on the Maynooth campus. At UCD Campus, the number of available charging points fluctuated greatly between 3 and 20 during the observation period. Most chargers were available in the somewhat remote UCD Park 4. However, these have a very low charging speed. The faster chargers at the central locations UCD 1, UCD 2 and UCD 3 were generally less numerous and rarely available. The charging points at the Maynooth campus behave similarly. The different availability of charging points at the two locations was also confirmed in the interviews. Respondents on the UCD campus were more likely to indicate that it is easy to find an available charger, and accordingly most respondents were satisfied with the availability of charging points. This applied to only a small proportion of respondents on the Maynooth campus (Figure 17).

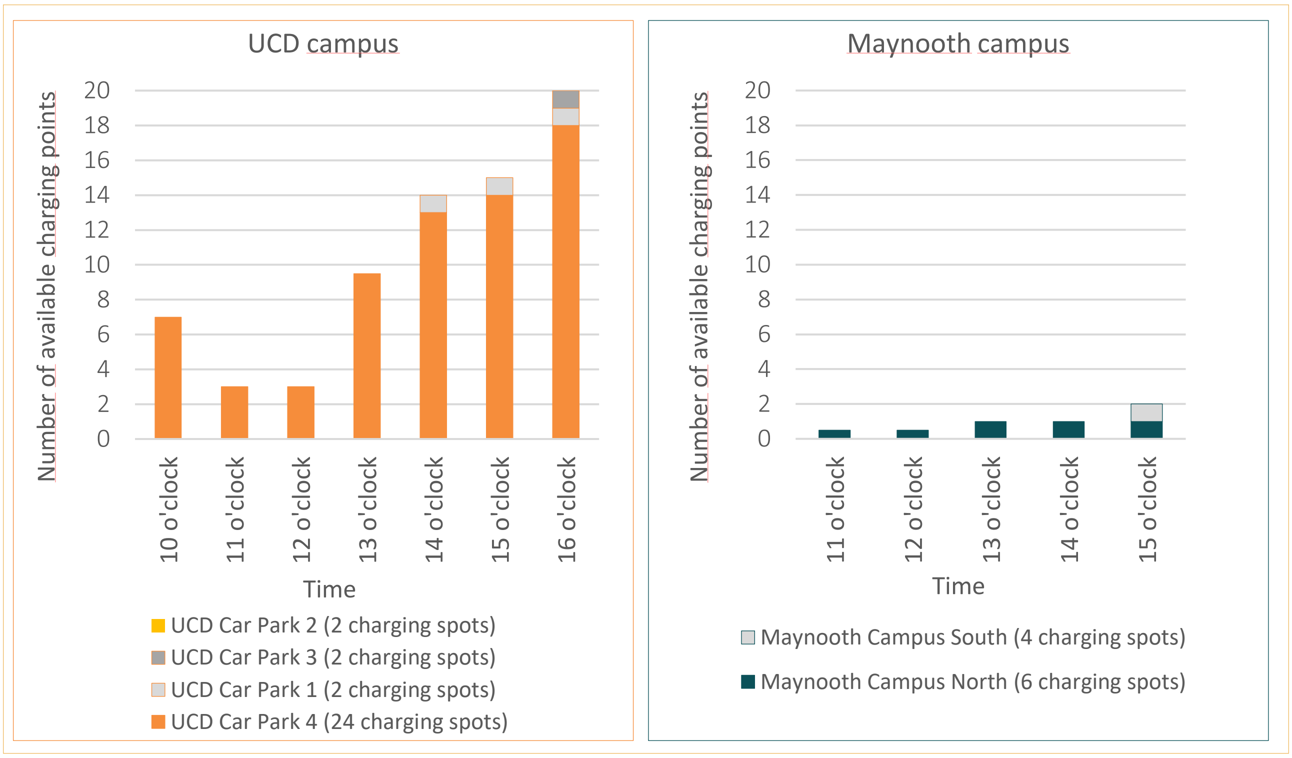


Figure 16. Availability of charging points on UCD and Maynooth campus: Observation

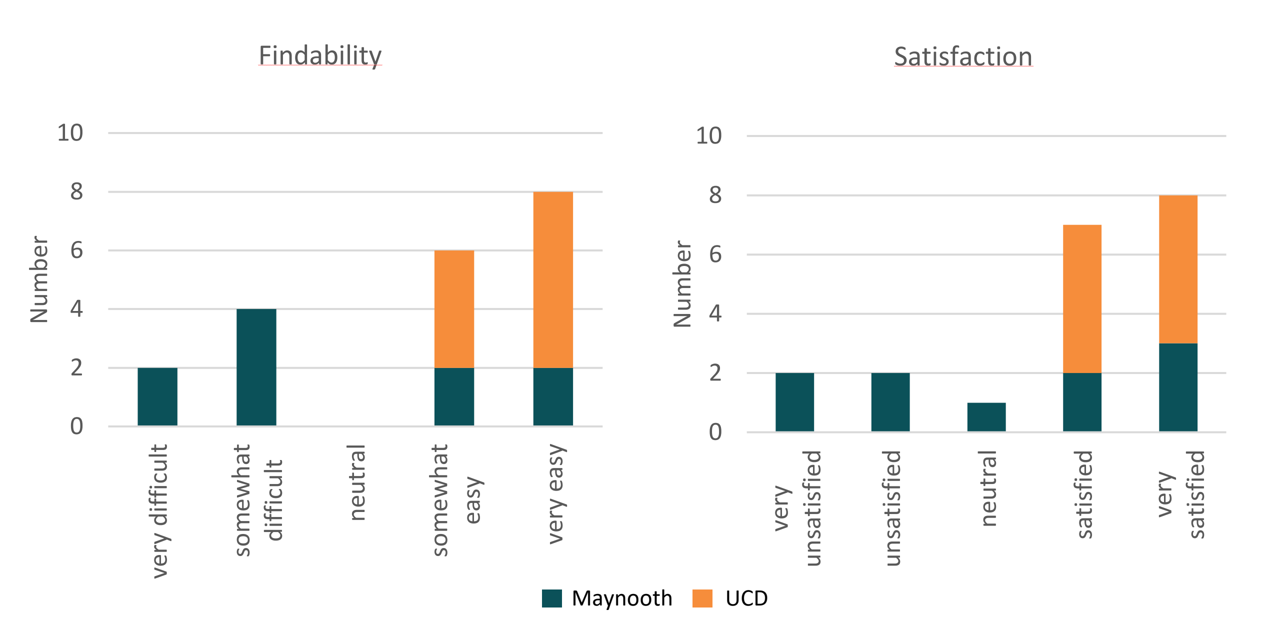


Figure 17. Availability of charging points: User perception of findability and satisfaction

Summary. Observation and interviews showed that *availability* of chargers was a problem at the Maynooth campus and therefore very important there. This situation arose because, in addition to the already few charging points, vehicles kept blocking the charging stations even though they were no longer charging. At the UCD campus, charging points were available but with a rather slow charging speed. Thus, the factors *charging price*, *time,* and *availability* were of the same importance.

5.3.2. Useful interventions to improve availability

With regard to possible strategies to improve the availability of charging stations, respondents first expressed their ideas on how this could be done (Figure 18, T1). Even though the respondents were told that it is not possible to install more charging stations, the majority at both locations suggested improving the infrastructure through additional charging stations and parking spaces or improving the hardware of charging stations. Besides, respondents from both campuses felt that the introduction of restrictions, such as time limits or the levying of charging and parking fees, could improve the situation, too. Also at both interview locations, ideas were expressed on how to increase the availability of charging stations by using EDP through information exchange. In Maynooth, a booking tool or an information tool could be helpful. While at UCD, the focus was on the findability of the charging stations.

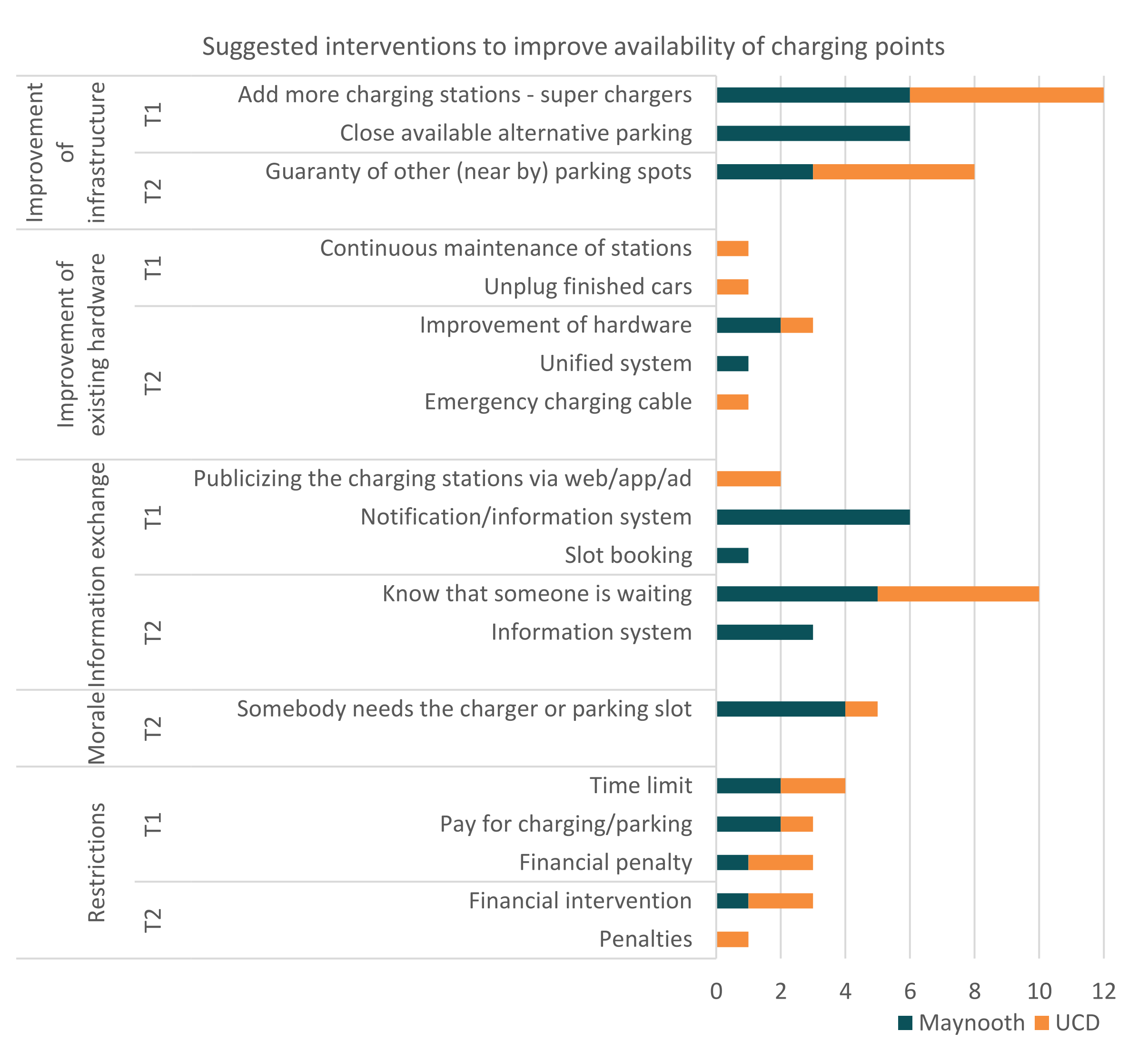


Figure 18. Interventions for improving availability of chargers mentioned by respondents

When asked for the willingness to leave the charging station after receiving a minimum charge during peak hours, only three respondents (Maynooth: n = 2, UCD: n = 1) reported being unwilling to leave the charging station. The extent to which the incentives – *cashback*, *points*, *gift cards,* and a guaranteed *free charging station* the next day – are helpful in motivating people to release a charging space was assessed differently at the two campuses. At UCD, *cashback* and a guaranteed *free charging station* could help to free the charging station; *gift cards* not. Here, *cashback* was rated to be more helpful than *points* and *gift cards*. In Maynooth, by contrast, none of the incentives were found to be helpful (Figure 19). In contrast to incentives, but in line with the free opinions expressed before, respondents at both campuses rated different types of information as helpful in order to free up a charging station. Thus, the information of the a*vailability of a parking spot*, information that *others need* the charging spot, and *communication* between users are all helpful to facilitate leaving the charging spot (Figure 19). In addition to the ratings, respondents could suggest further interventions to improve availability for the second time (T2). The freely mentioned suggestions were similar to the ideas expressed at the beginning (T1) and again related to *information exchange*, *improvement of infrastructure* and *hardware*, as well as *restrictions*. In addition, respondents felt that *morale* could serve as a driver to free up a charging point (Figure 18, T2).

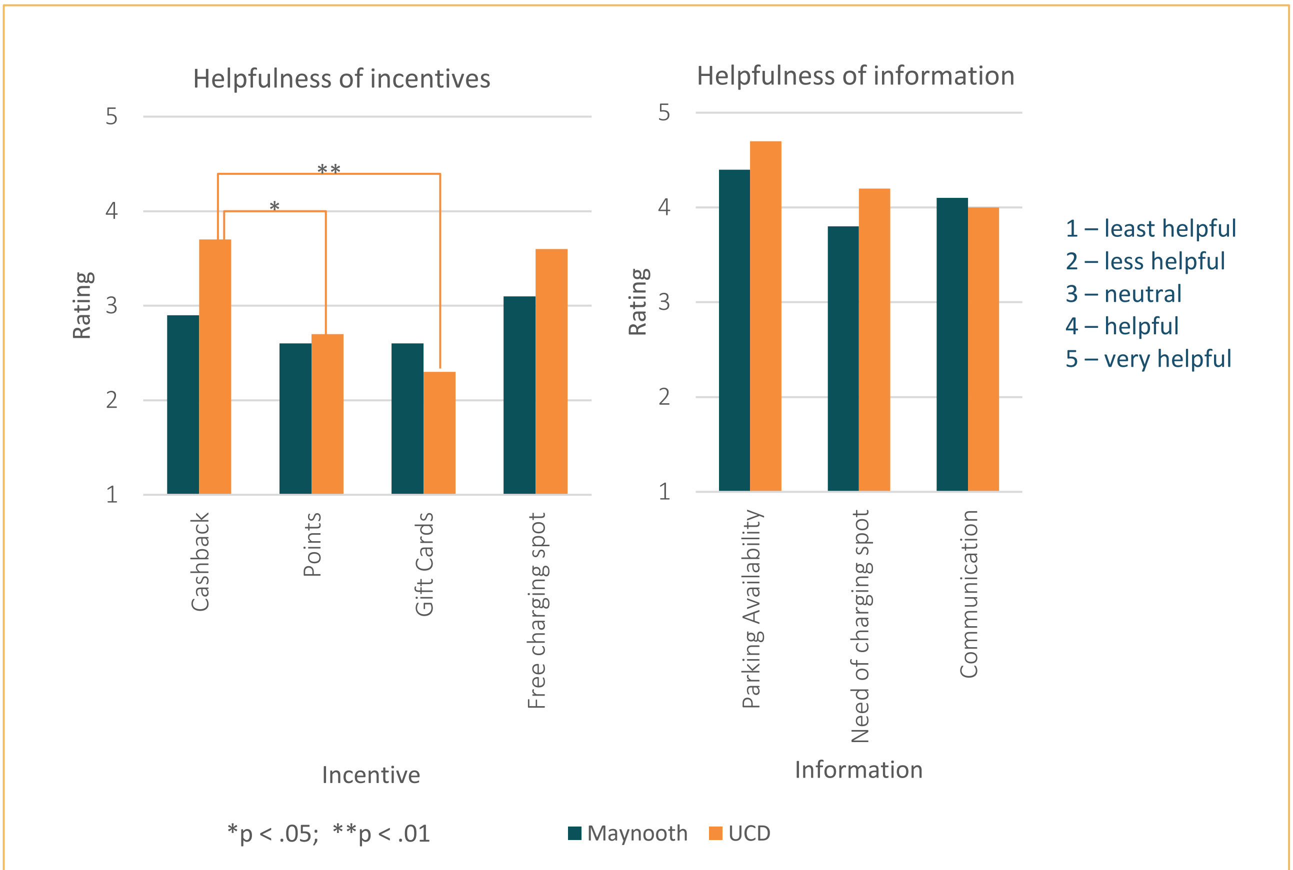


Figure 19. Respondents' ratings of the helpfulness of strategies for motivating users to free up a charging spot.

Summary. Incentives have been shown to be of little help in getting users to vacate their charging point after they have received a minimum charge. On the other hand, the provision of *information*, such as the *availability of a parking spot*, the information that *others need* the charging station, or *communication* between users, were rated as helpful to increase the availability of charging stations. Also from the free expressions, the need for *information exchange and communication* became apparent. Moreover, restrictions, such as *pricing*, could improve the availability of charging points from the users' point of view.

5.3.3. User requirements for an information/communication platform

In the third part of the interview, the idea of an information and communication platform was presented to the respondents. When asked about their attitude towards this platform, the respondents expressed both benefits and concerns. Most respondents at both locations liked the idea and expected benefits from the platform, such as the possibility to book time slots at a charging point, help in finding parking and charging spaces, and easy communication within the "charging community". At the same time, respondents also indicated their concerns, mainly related to the coordination of users and the users themselves, as they might not use the platform at all, not be able to use it or misuse it. In addition, respondents were concerned about problems with data protection and difficulties with technical implementation.

In order to capture concrete user requirements for the platform, the respondents were provided with two concrete scenarios as examples in which the communication platform could be used.

Scenario 1 = freeing up a charging station: "You were just at a charging station and have finished charging your EV. To free up the charging station for other users, you need to drive away and find a parking space. This turns out to be difficult, as most of the parking spaces are already occupied. But now you have the opportunity to use the new communication platform to contact others. That means you could contact someone via the platform who is looking for a free charging station and offers you his parking space."

Scenario 2 = searching for a charging station: "You are now in a situation where you need a free charging station to charge your EV and have a free parking space to offer."

After each scenario, respondents were asked *what* information they would need from the other user(s), *when* they would need the data and *how* they would like to receive the data. It was found that the required information was very similar in both scenarios: Both when freeing up and searching for a charging station, respondents stated the need of information about the location and time. This included information about the exact charging or parking location, but also information about the immediate surroundings. The time information was either the specific time when a charging or parking space is or will be available, i.e. the current charging status of a vehicle could also be used as information about the expected time of availability. In addition to location and time, respondents requested information about the charging price when searching for a charging station. The time at which the respondents wanted to receive the information differed between the scenarios. To free up a charging station, respondents needed the information depending on their SOC: when the car had a sufficiently high SOC or half an hour before it was fully charged. When searching for a charging station, respondents indicated very different times as relevant for obtaining information, ranging from the time *whenever a charging spot gets free*, the time *before or when arriving*, the time *when searching for a charging point* to *the night before*. It can be concluded from this that information about the availability of charging stations should be available at all times and continuously. When asked how they would like to receive this information, respondents also indicated varying preferences or no preference at all. Most wanted a text form, but did not specify how. Some respondents preferred instant communication, e.g. via an app, while others favoured communication via phone notifications. One respondent suggested an alert function.

Summary. The respondents were positive about an information platform and expected benefits from it. However, they also expressed concerns about whether this platform could be implemented and used appropriately. It became apparent that the respondents wanted security and plannability. To ensure finding and using a charging station as well as finding a parking space before or after charging, constant information about the availability of charging and parking spaces, including prices, would be a basic requirement. Further to information on (expected) availability in terms of time, the platform should provide specific and comprehensive information on the location of charging and parking spaces. All information could be provided by displaying the locations and availability times as well as through a system notification or communication between users. However, as some respondents feared that the spaces could be occupied more quickly by other users, a booking system would be helpful.

Communication could also be an option to address the users' morale and thus motivate them to free up a charging station. Confidentiality and data protection are very important, especially when it comes to communication between users. Essentially, the information platform should contain the functions and features shown in Table 15.

Table 15. User requirements for an information platform.

Function/ feature	Specified content	Type of implementation
Information on the availability of charging points	Information on times of available charging points	- Display currently available charging points - (Display SOC of charging cars at a station) - Notification, when a charging point gets available
	Information on locations of available charging points	- Display locations of charging points in general - Display locations of currently available charging points - Notification when a charging point gets available
Information on the availability of parking spaces	Information on times of available parking spaces	- Display currently available parking spaces - Notification, when a parking space gets available
	Information on locations of available parking spaces	- Display locations of parking spaces in general - Display locations of currently available parking spaces - Notification where a parking space gets available
Booking system for charging points	Search for charging point	- Select time of charging - Select charging type - Select charging location - Display charging prices - Display charging alternatives
	Booking of charging point	- Reserve charging slot at charging point - Enable payment processing for reservations
Booking system for parking spaces	Search for parking space	- Select time of parking - Select parking location - Display parking prices - Display parking alternatives
	Booking of parking space	- Reserve parking space - Enable payment processing for reservation
Information on SOC	Information on SOC of own EV	- Display SOC of your own EV - Notification when a pre-set SOC is reached
User communication	Communication between users	- Enable instant communication between users via text messages
Data protection	Data protection & privacy	- Ensure the users' privacy - Display privacy policy

5.4. Summary and recommendations for an information and communication tool for the Dublin testbed

In April 2023, a user requirements analysis based on an observation study and twenty face-to-face interviews on the Maynooth and UCD campuses was carried out in order to answer the research questions:

RQ1. What is the current usage situation from the users' perspective?
RQ2. What interventions would be useful to improve the situation?
RQ3. What are user requirements on an information/communication platform?

Regarding the current usage situation (RQ1), observation and interviews showed that a*vailability* of chargers was a problem at Maynooth campus and therefore very important there. At the UCD campus, charging points were available but with a rather slow charging speed. Thus, the factors *charging price*, *time,* and *availability* were of the same importance.

In order to improve the availability of charging stations (RQ2), the *exchange of information* could be helpful, as could restrictions, such as *pricing*.

Thus, the respondents were positive about an information platform (RQ3) and expected benefits from it, but also expressed concerns. This leads to the following recommendations for the tool:

Recommendations for an information and communication tool in Dublin:

(1) Basically, provide constant information about the availability of charging and parking spaces, including prices. Further to information on (expected) availability in terms of time, provide specific and comprehensive information on the location of charging and parking spaces.

(2) Provide all information by displaying the locations and availability times as well as through a system notification or communication between users.

(3) Integrate a booking system to ensure charging and parking at a desired time and location, including payment processing.

(4) Guarantee the users' privacy and provide information about data handling and data protection regulations.

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