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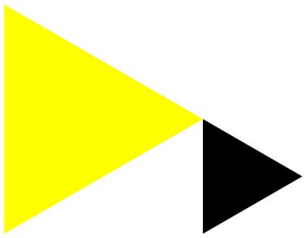

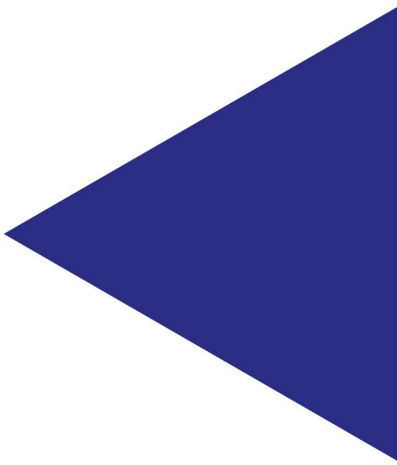

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User motivations and requirements for Vehicle2Grid systems

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Abstract
Vehicle2Grid is a new charging strategy that allows for charging and discharging of Plug-In Hybrid Electric Vehicles (PHEV) and Full Electric Vehicles (FEV). The discharged energy can be supplied back to the (local) energy grid, enabling for grid alleviation, but can also be supplied back to the household in the case of a Vehicle2Home connection. Vehicle2Grid is an innovative and complex systems that requires adequate input from users if the local energy grid is to fully benefit from the discharged energy. Users have to be willing for the *State of Charge* of their EV to be adjusted in order for the Vehicle2Grid system to actually discharge energy from the EV. However, limiting the potential range of an EV can act as a barrier for the use of a Vehicle2Grid system, as discharging might cause uncertainty and possible range anxiety. Charging and discharging an EV through the use of Vehicle2Grid is therefore expected to change user's routines and interactions with the charging system. Yet few Vehicle2Grid studies have focused on the requirements of a Vehicle2Grid system from the perspective of the user. This paper discussed several incentives and design guidelines that focus on the interaction users have with a Vehicle2Grid system in order to optimize user engagement with the system and integrate user preferences into the complex charging strategy. Results were obtained through a brief literature study, from a focus group as well as from two Vehicle2Grid field pilots. At the end of the paper, recommendations for further research are given.

Keywords: Vehicle2Grid, electric vehicle, user research, charging infrastructure, the Netherlands.

1. Introduction

The implementation of Vehicle2Grid as a new and complex technology requires insight into the needs and behavior of the potential users of such a system. Users are expected to handle a Vehicle2Grid charging system differently than with a regular charging system, which may change the behavior, habits and routines of the user. The use of this new technology raises questions: who is the potential user of a Vehicle2Grid system? What are the obstacles and motivations for using a Vehicle2Grid system? What are guidelines/requirements for the interaction between the user and a Vehicle2Grid system?

The Vehicle2Grid project at the Amsterdam University of Applied Sciences has focused on the development of a Vehicle2Grid system: a system in which a bidirectional charging station can both charge and discharge an electric car. The purpose of discharging an electric car is to send the energy from the car back into the energy network in order to balance peaks in the energy network. In addition, a Vehicle2Grid connection can also be used to discharge the energy from the electric car and thus provide a household with energy. The research project was designed and executed with different partners in the consortium (Amsterdam Smart City, Alliander, Engie and Mitsubishi Motors) who were able to construct a working Vehicle2Grid system.

This paper will first discuss recent findings on user motivations and acceptance on smart charging strategies. Subsequently, the findings from a focus group with EV drivers aimed at exploring possible usage of a Vehicle2Grid system is discussed, as well as the results from a pilot project whereby two households tested a Vehicle2Grid system. Afterwards, results are discussed and presented.

2. Literature review

Several studies have focused on the perception of end users on smart and controlled charging strategies. Schmalfuß et al. (2015) investigated the motivation among ten electric vehicle (EV) drivers to take part in a smart charging program and the benefits that users experienced during smart charging. Participants used a smart charging application with the use of a full electric car and were questioned about their motivation and perceptions regarding smart charging during a five-month test. Participants could adjust the settings for the charging process via a smartphone application, such as the departure time and the minimum *State of Charge*. First of all, the researchers conclude based on their findings that smart charging/controlled charging can be integrated into the everyday routine of EV drivers, as long as the EV drivers can estimate where they need to be the next day, when they have to be there and how many range they need for this. The two main motivations for the use of a smart charging strategy were mainly to contribute to the integration of sustainable energy, followed by providing a contribution to a stable energy network. Although financial benefits were not mentioned as main motivations, a financial advantage could create a balance by serving as a counterpart to the limited flexibility and extra effort the user has to invest into the use of the system. One of the experiences mentioned by users in this study was the planning aspect, in which one had to think ahead about the journeys and possibly to experience a small(er) range because they had set the minimum *State of Charge* lower than with a regular linear charging strategy. Another possible disadvantage that the participants considered prior to the trial was the lack of data privacy. However, this disadvantage was no longer mentioned by the users once they had experience with smart charging. In addition, the researchers also conclude that reliability of technology, access to smart charging from other devices and further improvements of the car, such as a large battery capacity, are necessary to further increase the acceptance of smart charging systems among consumers.

Research by Will & Schuller (2016), in the form of a survey, shows a high degree of acceptance of the concept of 'smart charging' among end users, whereby the researchers emphasize the need for demonstrating the benefits to the users. The most important influential factors on this acceptance of smart charging are the contribution to network stability and the integration of renewable energy. They also concluded that financial compensation for participation in smart charging is not an influential factor and that users have different expectations of the level of financial compensation that could be received, with an average of 20% cost reduction on their monthly charging costs. In addition, the researchers recognized that a number of users were afraid that they had to reduce their flexibility, on which the authors stated that users should be offered transparency.

It is striking that a large-scale survey conducted by Bailey & Axsen (2015) shows that the majority of EV owners would be more willing to have the control of the charging session controlled by another party, such as an energy supplier, if a monetary incentive is used, such as a discount on the energy bill, then when sustainability benefits, such as better use of renewable energy, are provided. However, they conclude that an environmental incentive was also perceived as attractive by certain segments of respondents. In addition, these researchers found that respondents mainly expressed concerns about privacy and loss of control with utility controlled charging.

From the above studies we can conclude that users of a smart charging system attach great importance to the integration of renewable energy into the energy network. In addition, there is a certain ambivalence regarding the financial compensation. However, we can conclude that a financial incentive, even if it is not used as a motivation for using a smart charging system, can be used as a compensation. Finally, this literature also shows that the user must be well informed about the privacy of the (charging) data before using a smart charging strategy. Based on these findings, questions related to the role of financial incentives remain, but also questions related to possible guidelines and requirements for a Vehicle2Grid system to be attractive for the user. The studies mentioned above largely relate to smart charging, but not always include the bidirectional charging functionality which generally demands more flexibility from the user than regular smart/controlled charging. In this paper we present findings on more detailed motivations and barriers of using a Vehicle2Grid system. We will also present findings on design guidelines and incentives, such as a gamification mechanism, that can be used to optimize user engagement with a Vehicle2Grid system.

3. Research design

Within this study two forms of consumer research were carried out: two focus groups with EV drivers to gather insights on potential motivations for the use of a Vehicle2Grid system and a longitudinal pilot project whereby Vehicle2Grid systems were installed and tested at two households.

Focus Group

At the start of the project in 2015, two focus groups were organized to gain insight into the behavior and needs of users. Because this is an explorative qualitative research, the interviews and discussions are valuable to get to know the user. Participants were engaged in sustainable energy and/or electric mobility. The focus group involved two sessions with 8 and 4 people respectively.

In preparation for the sessions, participants received a questionnaire that included general questions about energy, sustainability and mobility, which they had to fill out in the previous week and explain with daily activities. By having participants think about these aspects before the start of the focus group, they were well prepared for the focus group sessions.

The session consisted of various activities, with an introduction as starting activity in which Vehicle2Grid concepts were explained. A second activity involved questions about how the Vehicle2grid concept would fit within the current lifestyle of the participant and what they thought should be adjusted before they would use it themselves. The participants discussed the questions and formulated their general answer. The final part of the session consisted of a discussion between participants about their perceptions and interpretations of the Vehicle2Grid model. To define the discussion regarding barriers, expectations and motivations, possible screenshots of the Vehicle2Grid application were presented.

The aim of the focus groups was to gain a better understanding of the attractiveness of a Vehicle2Grid system for the user, based on: (I) current use of their EV, (II) motivation and obstacles to using a Vehicle2Grid system and (III) recommendations and guidelines for the interaction between the user and the Vehicle2Grid system.

Pilot Project

During the pilot projects, two users tested the Vehicle2Grid system from August 2016 to December 2017. Both households were already familiar with driving a Plug-in Hybrid Electric Vehicle and both households used photovoltaic systems. For the pilot project, one households used a PHEV (Mitsubishi Outlander) for the Vehicle2Grid system, the other households used a FEV (Mitsubishi i-MiEV). The Vehicle2Grid system consists of a bidirectional charger on the user's driveway and a smartphone application that can be used to start a charging session from a distance. In this application, the charging session can be started by entering a departure time with the preferred percentage (*State of Charge)* the battery must have at the indicated time of departure.

Additionally, two social experiments took place during the pilot project. During the first social experiment, users received an amount of points for their charging sessions, based on the variables entered in the app. The more flexibility they provided the Vehicle2Grid system to discharge the EV battery through a long connection time and a low preferred *State of Charge* at the time of departure, the more points they received. Additionally, users were given the score of the other user as well for comparison. The second social experiment provided users with a small financial incentive per charging session (either €0,02 per kWh charged or €0,14 per kWh discharged during peak hours).

The pilot research has been set up with three concrete goals: (I) evaluation of the Vehicle2Grid system from the user, (II) collect practical design tips and possibly new functionalities and (III) explore suitable incentives and motivations for the use of a Vehicle2Grid system.

During the pilot project, users kept a diary in which they stated how often they used the car, how much they drove around and what their charging habits were (e.g. connection time of the EV to the charger, preferred *State of Charge* when leaving). During the pilot project, face-to-face and telephonic interviews were held with both participants to gather feedback and recommendations on the functionalities of the system and the incentives provided to the user.

4. Results

Focus Group

An important motivation mentioned by participants to use the Vehicle2Grid system is to make optimal use of sustainable energy. This includes both charging the EV with green energy and optimizing the demand for energy in the local energy network so that sustainable energy can be utilized better. The Vehicle2Grid system can help users by making them aware of their energy consumption and the type of energy they use.

The focus groups also showed that a financial reward was expected by the users in order to use a Vehicle2Grid application. The majority of the participants argued during the focus groups that using a Vehicle2Grid application requires a certain amount of effort and flexibility from the user. These participants concluded that, in order to compensate for the effort and flexibility, they expected a reward in the form of financial compensation.

In addition, use of the Vehicle2Grid system should be made easy for the user, giving him/her control. This means that the user can adjust the settings to their own personal preference and have the possibility to stop a charging session, for example when the user unexpectedly needs the car during the charging session. The user must, in an easy way, be able to plan upcoming charging sessions and adjust the system to his/her own charging and driving requirements. In addition, safeguarding privacy is also seen as important, whereby users do not want data resulting from their charging behavior to be shared with commercial parties.

Finally, so-called 'nice-to-haves' can be added; functionalities that make the use of the app more interesting and, to a certain extent, more fun. Think of the possibility to communicate with other users or compare charging sessions by means of a gamification application, such as comparing scores between users. In addition, insight into the charged or discharged energy, as well as a link with the own solar panels, would also belong to one of these 'nice-to-haves'.

Pilot Project

Both users were intrinsically motivated and committed to the objectives of the Vehicle2Grid system, such as energy grid relief and optimal use of sustainable energy. An important part of this intrinsic motivation is the link between the system and the solar panels of the users, which has also been an important motivation for both users to participate in the project. Using the energy from their own solar panels could therefore be a strong value proposition towards EV users who also own solar panels.

Although user 1 became enthusiastic about the gamification functionality within the application, a gamification system with points, the participant indicated that in order for a point system to be effective value and purpose must be linked to these points. The goal of obtaining the points must also be connected to the goals of the user. For example, user 2 indicates that she wants to see the number of points in relation to a certain value, where one point could equal a value of € 0.10. User 1 would prefer to exchange his points for other energy-efficient gadgets, allowing him to collect points to achieve that goal, an energy-efficient gadget, over and over again. Both users indicate that they would like to use the points received from the gamification functionality to purchase a product or get a discount. Redeeming this number of points could be realized in a digital shopping environment, where the user can choose what they would like to receive in exchange for their points. A shopping environment could in principle be realized with both a gamification/points system as well as a financial compensation: €20,- in financial compensation could be equal to an energy-efficient lamp, but 20 Vehicle2Grid points could also be equal to the same lamp. This approach could vary depending on the motivation of the user. Since both users indicate that they want to make use of a Vehicle2Grid system in order to make optimal use of (self-generated) sustainable energy, the link between sustainability and the gamification system could also be made here, e.g. by changing the name of the points and calling them 'sustainability points' or 'green energy points'.

In addition, both users could benefit if they would be able to compare their points they received per charging session. This makes it possible to compare the charging sessions with each other on the basis of points received and also makes it possible for users to compare the points from the current charging session

with the points they received in previous charging sessions. This also complements the overall information provision in the app, where users can see an overview of their charging sessions

A financial incentive does not seem to be attractive for both users. Although both users indicate that a reimbursement is not a motivation to use a Vehicle2Grid system, it is interesting to see that the amount of money that user 2 would deem reasonable for a financial compensation per charging session (approximately €0,25, if the EV were also to be connected to the charging point when not in use) is not perceived as attractive by user 1. The role of a financial incentive therefore remains ambivalent.

Finally, a requirement for both a gamification system and financial reward is transparency, where the calculation of points or financial return is explained and it becomes clear to the user how they can set new goals and improve oneself (acquiring more points/money). This is also related to the aspect of being able to control of the charging session, in which the user can choose how many points/money they wish to receive per charging session on the basis of adjustable settings in the app.

5. Discussion

The results of the focus groups have given direction to further development of the functionalities of the Vehicle2Grid proposition and application developed within the project. A limitation was the limited number of participants. Another possible limitation is the rapid development of electric vehicles that make it possible to change the image around Vehicle2Grid, electric driving and charging. It is therefore advisable to regularly repeat such consumer research during this phase of development, to monitor the effects of the developing within the EV sector and to reach a broader audience of users; either with focus groups or with a survey.

The pilot research was based on two users, making it difficult to generalize findings. Although the results of the pilot research are in line with the results from the literature review and the focus groups, follow-up research should ideally focus on a larger group of (possible) users in order to gain further insights. This larger group should not only include the 'innovators' but also the 'early adopters'; the users who do not directly belong to the first group of consumers who purchase new technology and who might use this new technology based on other interests and motives. Particularly in the area of incentives (financial or gamification) and the functionalities of the application, a broader study could build on earlier research with the existing research questions.

Additionally, for further design and implementation of Vehicle2Grid systems, practitioners should take possible different motivations into account, as well as functionalities and designs that meet the needs of (possible new) users.

6. Conclusion

Based on the findings in the literature, the focus groups and experiments in the pilot setting, the following conclusions can be made.

First, the use of renewable energy in general and own solar energy specifically seems to be the main motivation to use a Vehicle2Grid system. As Schmalfuß et al (2015) therefore also point out, smart charging applications should mainly be promoted by linking the system to the positive contribution to the (local) energy network and the optimization of renewable energy. As the research in the pilot settings shows, the link with the users' own solar panels is a great addition for the user. The question remains if this is also the case for larger groups of users.

Second, a financial reward seems to be a good compensation for the flexibility that people give up, but should not be the main incentive. The focus groups, the user research and the literature show that a financial incentive is often not a motivation to participate, but could be a compensation for the adjustments in flexibility, provided that the amount of money is considered as reasonable by the user. In addition, a financial compensation does not seem to distract from other motives for taking the Vehicle2Grid system into use. The use of a financial incentive is still ambivalent, but our findings are in line with the findings in the literature and through our study we gained a bit more insight into the role of a monetary reward as a compensation mechanism.

Third, the information provided by the application should inform the user of the charging process. By providing more information about both the specific charging session and a historical overview, the charging process can be made more transparent to the user. This also makes the contribution to a stable network more transparent to the user and reinforces the feeling of control, as mentioned during the focus groups. The information provision in the application could be extended in three ways: (I) a historical overview, giving users an overview of previous charging sessions, with a concise overview of each charging session, (II) information per charging session about the charged and discharged energy, specifically mapping when the car is charged and discharged during the charging session and how much energy is involved and (III) in the case of a Vehicle2Home setting, information could also be provided about how much self-generated solar energy has been used to charge the car.

Fourth, a gamification system was valued by the users in the pilot setting and is related to the feedback from the focus groups, which showed that the system should be pleasant to use. An important condition for the implementation of a gamification system is that the points awarded to the user have both a value and a goal. An obvious solution would be a digital shopping environment in which a user can exchange the points as they wish, for example, on an energy-efficient product or a discount on the monthly energy bill.

Fifth, although planning and control were mentioned as possible barriers during the focus groups, both the literature (Schmalfuß 2015) and users in the pilot setting show that this does not have to be an obstacle. The customizable settings in the app offer sufficient opportunity to adjust the charging session based on your own schedule. This also strengthens the feeling of control over the charging session. Although both participants in the pilot setting used the EV as a second car, the interruption of the charging session happened rarely.

Finally, the use of a Vehicle2Grid system must be transparent. In addition to the aforementioned information provision about the operation of the system with regard to the charging sessions, the literature and the focus groups show that (potential) users of a Vehicle2Grid system need data privacy: which data can be viewed by which party? This must be timely communicated before use, so that privacy does not form a barrier for the adoption of Vehicle2Grid technology.

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