D4.1 Guidelines for user-centered development of approaches for enhancing social acceptance and user collaboration

Final Version

Deliverable

Kreußlein, Maria: Research Group Cognitive and Engineering Psychology, Chemnitz University of Technology

Döbelt, Susen: Research Group Cognitive and Engineering Psychology, Chemnitz University of Technology

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  - **Sensitive**: Contains analysis or interpretation of results with policy-relevance and/or recommendations or policy-relevant statements
  - **Highly Sensitive Confidential**: Contains significant analysis or interpretation of results with major policy-relevance or implications, contains extensive recommendations or policy-relevant statements, and/or contain policy-prescriptive statements. This sensitivity requires SB decision.

DOCUMENT STATUS

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<td>TUC</td>
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<td></td>
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<td>Döbelt, Susen</td>
<td>TUC</td>
</tr>
<tr>
<td><strong>Verification by</strong></td>
<td>2018-12</td>
<td>Antonioli Mantegazzini, Barbara</td>
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<td><strong>Approval by</strong></td>
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<td>Medici, Vasco</td>
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ABOUT THE NEMoGRID PROJECT

The NEMoGrid Project is mainly focused on the definition of innovative business models that could ease the penetration of renewables into the distribution grid, with a particular emphasis on the definition of a peer-to-peer strategy based on the blockchain technology. The new business models will encourage the active participation of citizens and the assumption of their new role of prosumers, by allowing them to enter new markets as players. Among the tested scenarios, the most innovative one will be based on a peer-to-peer market. In this case, new decentralized platforms based on the blockchain technology will allow zero marginal cost transactions. In order to test the new business models effectiveness, a simulation framework will be developed. Each scenario will be evaluated base on a number of KPIs. Existing demo sites in Rolle (CH), Björklinge (SE) and Wüstenrot (DE) will be used to validate the business model that gives the best simulation results. Real loads will be controlled by the algorithms developed in the simulation phase. Technical developments within NEMoGrid will be supported with user research, gathering empirical data on prosumers decisions and interactions. The results will be used to develop an adoption model and to continuously refine the simulations.

www.nemogrid.eu
1 Consumer and Prosumer Requirements For Accepting Future Energy Business Models

The energy revolution and smart grids are two of the most important energy topics of the modern times. Recently, the demand for energy is growing while traditional resources of energy supply (coal, natural gas, and oil) will not meet the increasing energy demand any longer [01]. As a result, distributed energy resources (DERs) have become increasingly important. Distributed generation of energy “...can be defined as electric power generation within distribution networks or on the customer side of the network.”[02]. Further, DERs are a promising tool to integrate renewable energy. In consequence, DER energy is more environmentally-friendly than energy from the centralized energy production with e.g., fossil fuels in power plants. Moreover, DERs provide more flexibility to the distribution grid in times of high loads of consumption because the energy is produced where it is consumed. On top, this reduces the distribution and transmission costs and is in consequence more energy-efficient [03]. Their acceptance is a main contributor to the adoption [04] of these models. Hence, integration of user preferences and barriers is of fundamental importance in the design process, but research on acceptance of DERs and business models is scarce until now [04]. Recently Von Wirth, Gislason and Seidl [04] investigated drivers and barriers for the acceptance of these distributed energy systems. Results indicate that the awareness of local advantages could be a decisive argument promoting these systems. Furthermore, the authors conclude that the ownership of infrastructure fosters the acceptance of such systems. Most concepts, which promote sustainable-energy behavior, incorporate people as individuals motivated by self-interest [05]. As local energy approaches of production and consumption involve small communities, group-based approaches addressing motivational aspects of participation are interesting as well. A promising and often mentioned approach in the field of human-computer interaction to increase participant motivation is the concept of gamification. It is defined as “the use of video game elements, to improve user experience and user engagement” [11].

In the context of this Deliverable we want to present and discuss the methods and results of our conducted online-studies and a focus group. We have already examined the acceptance of different business models in general, which was discussed in Deliverable 2.3, Results regarding consumer/prosumer requirements. In the present Deliverable we want to verify the results with a larger European sample. Further, we investigated the design for interaction devices for all business models. The findings of these investigations formed the basis for the examination of an interface within the framework of a focus group. Here, we examined the usability of the user interface for the most innovative approach, namely the Peer-2-Peer business model. The spotlight was on gamification strategies to increase the motivation to participate. Finally, guidelines for a user-centered development of business models for DER will be created from the results.
2 Acceptance of all Business Models - European Online Study

In the present deliverable, we want to verify the results regarding user acceptance of new energy business models, which we published in Deliverable 2.3 with a larger European sample. In order to do so, we explain the procedure and the method of the study carried out in the following.

2.1 Method

We conducted an online survey between January and March 2019. Recruitment was carried out via the subject database of the Research Unit of Cognitive and Engineering Psychology of the Chemnitz University of Technology, our project website www.nemogrid.eu, University press releases and leaflets. Further, our project partner Sonnen GmbH distributed study information in their newsletter. In the following section, the structure of the study and variables of interest are described in detail. Subsequently, the results are presented and discussed in the sections below.

2.2 Procedure

The online study was divided into five consecutive parts. In the beginning, demographic information was collected (e.g., age, gender, country of origin). In a second step, questions were asked about user characteristics (prosumer or consumer) and current electricity consumption. Respondents should then provide details and their evaluations of the current Business-as-usual model (BaU). Subsequently, one of the three business models designed in the project should be evaluated with regard to acceptance and other factors. The business models were randomly assigned to the participants. Thereafter, we focused on the requirements that we compiled from the expert interviews for such models. These requirements were itemized and presented to the respondents, who evaluated them in the end. Respondents were asked to evaluate design options. Then, the respondents were requested to answer some questions about personality traits. Eventually, there was the possibility to register for the raffle as remuneration for their participation. Altogether, we raffled five times 20 Euro among the participants, which was transferred via Paypal or International Bank Transfer. The completion time took about 40 minutes.

2.3 Scenario Description

As the study represented an extension and validation of the results of the interviews and should allow participation for interested parties from different European countries, therefore the project consortium agreed to conduct the survey in English. The business model descriptions were aligned with regard to the respective user group (prosumer or consumer). The descriptions entailed the source from which pro- and consumers retrieve the energy (e.g., their own PV plant or the DSO) and the basic tariff structure (e.g., static depending on the amount of energy). Furthermore, the installed infrastructure (software and hardware; e.g., algorithms and storage) and possible effects of the business model are
described (e.g., shifting of energy-consuming activities). In the following, a section of the description entailed the composition of the costs and the components of the respective energy bill (e.g., quota of network service usage, time-specific energy costs). In the final part of the descriptions, financial benefits are indicated. The descriptions are in the ANNEX.

2.4 Sample

Overall, \(N = 178\) persons participated in the online study, with 88\% of all respondents coming from Germany. Further participants were from the Netherlands, Romania, Latvia, Finland, Denmark, Austria, Belgium, Italy, Russia, Sweden, Switzerland, United Kingdom. Of 178 participants, \(n = 113\) were prosumer and \(n = 65\) consumer. On average, they were \(M = 49\) years old (\(SD = 12\)). The majority (64\%) of interviewees were male. With regard to the level of education, most respondents indicate holding a university degree or higher. Figure 2. A total of \(n = 58\) respondents evaluated the DSO controlled business model, \(n = 57\) the Voltage tariff and \(n = 53\) the Peer-2-Peer approach. The income categories were equally distributed across the respondents (Figure 1).

![Level of Education](image)

**Figure 2.** Distribution of level of education (\(N = 178\)).

![Monthly Income](image)

**Figure 1.** Distribution of monthly income and city size in the sample (\(N = 178\)).

The majority of the subjects live in areas with less than 20,000 inhabitants (Figure 1). Regarding the current energy contract, 57\% of the respondents said that their loads are not controlled by the supplier. However, about a quarter of the respondents did not know if...
their loads might be controlled. One in two has a contract with the largest possible share of electricity from renewable sources (53\%). A third has a conventional contract with a typical grid mix (34\%). On average, the respondents have had their contract for 6 years. 66\% of the consumers thought about becoming a prosumer in the near future. The majority (67\%) of prosumers recently (within the last 3 years) started to own their energy plant. When asked what the most important reasons for users to switch to self-production are, we found that consumers particularly appreciate 1) the independence from the supplier, 2) the desire to save money and 3) the desire to contribute to climate protection. For prosumers, the contribution to climate protection was the most important factor (Figure 3). As we can see in Figure 5, the majority of prosumers never received subsidies for their energy plant. However, in case prosumers received some, then it was mainly remunerated with financial incentives by their supplier or by governmental funding. When asked about monetary savings, we get relatively high importance values (Table 1).

![Figure 3. Motivators to become a prosumer.](image)

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSO Planned</td>
<td>43.24</td>
<td>29.06</td>
</tr>
<tr>
<td>Voltage</td>
<td>36.44</td>
<td>30.12</td>
</tr>
<tr>
<td>P2P</td>
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<td>23.62</td>
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<tr>
<td>Consumer</td>
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<td>21.90</td>
</tr>
<tr>
<td>Prosumer</td>
<td>42.83</td>
<td>29.82</td>
</tr>
</tbody>
</table>

Table 1. Descriptive statistics for expected savings in while participating in a business model.
In addition, we also asked for self-assessed knowledge about the integration of renewable energies and grid stabilization on a 6-point scale. The higher the indicated values, the more they rated themselves as experts. Prosumers and consumers rated their knowledge on the integration almost equally high ($M = 4.24; SD = 1.17$). Considering grid stabilization, respondents rated their knowledge a little bit minor ($M = 3.85; SD = 1.36$). However, we did not find differences between the user groups. Further, we were interested in whether respondents have concerns with regard to energy security. As can be seen in Figure 4, the main concern of all respondents is that they no longer have any fossil fuels available. Regardless of the user group, we found high environmental concerns for all respondents.

![Figure 5. Absolute frequency of subsidies for prosumers.](image)

Do you receive one or more of the following subsidies for your energy or energy plant or do you plan to apply for them in the near future? ($n = 113$)

- Financial incentive by the Energy Supplier/DSO (feed-in-tariff)
- Promotional loan
- Governmental funding program
- Tax benefits and depreciation
- Revaluing my (real) estate
- Other

![Figure 5. Absolute frequency of subsidies for prosumers.](image)

![Figure 4. Descriptive results of concerns regarding the energy security in the future by user groups ($N = 178$).](image)
We used items from the ISSP questionnaire [17]. These items have been used extensively to construct indices of environmental concern; however, the theoretical rationales for such constructions have varied widely. For the present study, we selected only those items that addressed the extent to which people are concerned about the future of the environment. We therefore chose two items (3 & 4 in Figure 6). Response options ranged from 1 (strongly disagree) to 5 (strongly agree). Items were reverse coded before including them in the analyses. The items’ reliability alpha coefficient was .59 and their zero-order correlation was .42 (p < .01). We also found high scores for all user groups in terms of perceived behavioral control. Perceived behavioral control was measured with the following two items: "It is just too difficult for someone like me to do much about the environment," and "There is no point in doing what I can for the environment unless others do the same." Response options ranged from 1 (strongly disagree) to 5 (strongly agree). Items were reverse coded before including them in the analyses. The scale’s reliability coefficient alpha was .55 and the zero-order correlation between the two scale items was .38 (p < .01).

2.5 DATA ANALYSIS

In order to generate guidelines, we compared the evaluation of the future business model with the BaU evaluations. Depending on the data distribution, parametric t-test or non-parametric Wilcoxon-signed-rank test were used for each variable to calculate the differences. The significance level for the test was $p = .05$. We then compared the business models (3 models) against each other to highlight the advantages and disadvantages between the models. To test the differences between the business models, a parametric analysis of variance (ANOVA) or an $H$-test (Kruskal-Wallis) with a significance level of $p = .05$ was used depending on the data distribution. In order to derive user group-specific recommendations, depending on the data situation, either parametric independent t-tests or (pro- vs. consumer) or non-parametric Mann-Whitney-U tests for each variable performed. The null hypotheses of each of the above-mentioned tests assume that there are no differences between the tested groups. The groups are therefore similar. In the case that
the critical value, the significance level of \( p = .05 \), is not exceeded, the alternative hypothesis is assumed, which states that there is a statistically significant difference between the groups. For more information on the test procedures, please see [07].

2.6 Results

Acceptance

As already mentioned before (Deliverable 2.3), acceptance is crucial for a successful implementation. Two methods were used to determine the acceptance of the business models. On the one hand, we asked for the willingness to participate in the business model in a closed (Yes/No) answer format. This showed that an average of 67\% of those surveyed agreed with the business model presented to them and could imagine using it (Figure 7).

![Figure 7. Acceptance by willingness to participate in the business model.](image)

On the other hand, we used the standardized measuring instrument of the Acceptance scale [16] to evaluate the usefulness and satisfaction with the model. It is a simple 5 point-Likert scale, with nine opposing dimensions. It became apparent that the future business models were not considered more useful in general terms (\( Z(178) = -0.123, p = .45 \)), but more satisfactory than the BaU model currently in use (\( Z(178) = -1.98, p = .02 \), Figure 8). However, we did not find differences in evaluations of satisfaction (\( U = 4028.50, z = 1.08, p = .28 \)) and usefulness (\( U = 3795.50, z = .37, p = .70 \)) between consumers and prosumer, neither on a general, nor on a business model level.
The results of the non-parametric tests are listed below. All tests are not significant, which indicates that the acceptability is the same in all models.

- Usefulness scale
  - DSO $U = 346.00$, $z = -0.70$, $p = 0.48$  
  - Volt $U = 497.00$, $z = 0.24$, $p = 0.81$  
  - P2P $U = 367.50$, $z = 0.95$, $p = 0.34$

- Satisfying scale
  - DSO $U = 393.00$, $z = 0.05$, $p = 0.95$  
  - Volt $U = 478.00$, $z = -0.02$, $p = 0.97$  
  - P2P $U = 390.00$, $z = 1.36$, $p = 0.17$

Perceived Ease of Use

Another element for the evaluation of acceptance concerns the Perceived Ease of Use [09]. The interviewer presented three different statements (Annex D) and asked the interviewees to indicate their agreement on a scale ranging from 1 = “Strongly disagree” to 7 = “Strongly agree”. In direct comparison between BaU and future models, we observe that respondents Perceived Ease of Use of future business models was significantly lower than the current business model ($t(177) = 10.366$, $p = 0.00^*$, $d = -0.96$). The rating of the BaU was 5.59 ($SD = 1.11$, $N = 178$) whereas the future models were only ranked with 4.14 ($SD = 1.73$, $N = 178$). Overall, prosumers rated the Ease of Use slightly better than consumers ($U(177) = 4299$, $z = 1.89$, $p = 0.058^*$, $d = 0.28$; prosumer: $M = 4.33$, $SD = 1.73$, $N = 113$; consumers: $M = 3.82$, $SD = 1.71$, $N = 65$). Perceived Ease of Use of future energy business models differed significantly. It was highest for the DSO planned, followed by P2P, neutral for the Voltage tariff ($H(2) = 21.07$, $p = 0.00$, $d = 0.69$). For more details see Table 2.
Table 2. Descriptive results perceived Ease of Use and rank list in non-parametric test.

<table>
<thead>
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<th></th>
<th>M</th>
<th>SD</th>
<th>Mdn</th>
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<td>4.91</td>
<td>1.36</td>
<td>5.00</td>
<td>113.81</td>
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<td>Volt</td>
<td>3.55</td>
<td>1.73</td>
<td>3.33</td>
<td>72.20</td>
</tr>
<tr>
<td>P2P</td>
<td>4.14</td>
<td>1.78</td>
<td>4.00</td>
<td>83.15</td>
</tr>
</tbody>
</table>

Perceived Usefulness

Again, the respondents were asked to indicate their agreement to three different statements (see Annex D) on a 7-point agreement scale. We see that respondents rated the Perceived Usefulness of future business models significantly higher than the current business model ($t(177) = -5.363, p = .00\ast, d = 0.51$). Further, we found, that prosumer rated the BaU models more positive than consumers ($U = 2668.50, z = -3.04, p = .002, d = 0.46$). However, prosumers and consumer did not differ in their evaluation of Perceived Usefulness of future energy business models ($U = 3440, z = -.70, p = .480\ast, d = 0.105$). We found no statistical significant difference between the Perceived Usefulness of future models ($H(2) = 2.91, p = .233$). DSO was rated the most useful. We cannot see any significant differences in the evaluations on the user level for the specific models (DSO: $U = 357.00, z =-.53, p = .590\ast$, Volt: $U = 462.00, z = -.25, p = .790\ast$, P2P: $t(55) = 0.29, p = .787\ast$). For detailed descriptive results see Table 3.

![Figure 9. Evaluation of future business models by user type.](image-url)
Willingness to Use

Another key factor for the survey and evaluation by the users is the stated Willingness to Use. Three different questions were raised within the questionnaire (see Annex D). The Willingness to Use was rated on a 7-point agreement scale ranging from 1 = "Not at all" to 7 = "Extremely" for the future business models. Overall, Willingness to Use was high with $M = 4.72$ ($SD = 1.91, N = 178$). Generally speaking, the Willingness to Use is equally high for both user groups and we did not find statistically significant differences ($U = 3635, z = -.11, p = .910$). Further, there was no clear statistical significant difference in the Willingness to Use different energy models and users (DSO: $U = 368.50, z = -.34, p = .720$, Volt: $U = 500.50, z = .29, p = .770$, P2P: $U = 337.50, z = .41, p = .680$). For detailed descriptive results, see Table 4.

Expectancy

Another much more comprehensive way of identifying requirements is by using open question formats. Above all, the issue of Expectations is of central relevance. In the course of the project, we have compiled the initial central requirements from in-depths interviews. These were then formulated in positive and negative statements and evaluated on a 5-level
scale from 1= "Strongly agree" to 5= "Strongly disagree". In addition to Expectations, it was also possible to evaluate concerns in relation to the presented models. The list of items can be found in Figure 10.
When I use this model I have the expectation...

Figure 10. Expectancy items and results for business models with 95% confidence interval. 1 = Strongly agree, 5 = Strongly disagree.
From Figure 10, it is clear that the respondents clearly agree with a few items regardless of the presented business models. A contribution to the integration of renewable energies seems to be a fundamental requirement for every model, as well as the stabilization of the grid. This goes alongside an innovative modern business model. In addition, the respondents expect to profit from the model. However, \((H(2) = 6.24, p = .044)\) Expectations regarding the personal effort vary considerably. In contrast to the Volt and P2P models, DSO is expected to require significantly less effort \((H(2) = 12.20, p = .002)\). In the P2P model the respondents expect the most influence \((H(2) = 6.14, p = .046)\). The costs seem to be most transparent for the P2P and also the Volt business model. The highest installation and bureaucratic costs are expected for the Volt and P2P model \((H(2) = 15.10, p = .001)\).

<table>
<thead>
<tr>
<th>Model</th>
<th>User</th>
<th>M</th>
<th>SD</th>
<th>N</th>
<th>Mdn/ Rank</th>
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<td>178</td>
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<td>Models</td>
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<td>1.89</td>
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<td>5.33/88.93</td>
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<td></td>
<td>Prosumer</td>
<td>4.72</td>
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<td>113</td>
<td>5.00/89.83</td>
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<td>1.87</td>
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<td></td>
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<td></td>
<td>Prosumer</td>
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<td>1.92</td>
<td>39</td>
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<tr>
<td>Volt</td>
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<td>4.69</td>
<td>1.99</td>
<td>62</td>
<td>5.33/89.80</td>
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<tr>
<td></td>
<td>Prosumer</td>
<td>4.70</td>
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<td>42</td>
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</tr>
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</table>

Notes: BaU = Business-as-Usual; Volt = Voltage Tariff; P2P = Peer-2-Peer; Future includes DSO planned Voltage Tariff and Peer-to-Peer

**Table 4.** Descriptive results for the evaluation Willingness to Use by groups.

Moreover, we were also interested in this part if and how prosumers and consumers differ in terms of Expectations. As can be seen in **Table 5**, we find significant differences for the user groups. Compared to prosumer, consumers are more concerned about the costs. Consumers think the effort will increase when using the business model and think that installation and bureaucracy hurdles are high. Further, they feel more restricted than prosumers.

<table>
<thead>
<tr>
<th></th>
<th>Consumer ((N = 65))</th>
<th>Prosumer ((N = 113))</th>
</tr>
</thead>
<tbody>
<tr>
<td>I don’t have to do much by myself.</td>
<td>101.78 (M = 3.17) ((SD = 1.15))</td>
<td>82.43 (M = 2.73) ((SD = 1.00))</td>
</tr>
</tbody>
</table>
I have to overcome hurdles such as the installation of infrastructure and bureaucracy.

\[ M = 2.45 \ (SD = 1.17) \]

I have to restrict my own consumption habits

\[ M = 2.77 \ (SD = 1.17) \]

I don’t know what to expect in terms of costs.

\[ M = 2.48 \ (SD = 1.17) \]

Table 5. Non-parametric test-results on concerns of business model participation.

Design of Interaction Device

From the literature, we have developed various approaches to improve the motivation and cooperation of users, which can be applied in the context of new technologies and renewable energies. The P2P model alone offers the greatest possible exchange and interaction between different user groups. Nevertheless, it is also important for the other models to evaluate strategies for increasing motivation, especially because they are easier to implement. We have had 18 items rated on a 6-tier scale from 1= "Completely not motivating" at all to 6= "Completely motivating" for these respondents. For better comprehensibility and readability, we have aggregated categories 1 to 3 in this report. Categories 4 to 6 are broken down in more detail in the figure, making it easier to identify the strategies that are assessed as most motivating. Additionally, we have combined some of the 18 strategies. We received 3 categories. These are 1) information about the net situation, 2) personal information and 3) information that allows social comparison.

At least 60% of all respondents rate the information as motivating. From this, it can be concluded that all three pieces of information should be presented. Whereby the majority of users who responded to the Volt business model rate most of the information at least largely motivating, only a third of the respondents of the P2P model do so (Figure 11). We also examined the extent to which information on personal consumption is motivating for the respondents. As shown in the Figure 12, the majority of the information is perceived as motivating. The display of personal earnings was rated as motivating by only two-thirds of all respondents. The change in energy consumption and the average energy consumption are considered by about 80% of the respondents per model as largely motivating.
With regard to gamification strategies that cover community aspects, it becomes clear (Figure 13) that the motivational effects are perceived as motivating by only every second person on average. More specifically, comparisons of savings or earnings with other pro- or consumers or communities seem to be rejected by the majority of respondents regardless of the model presented. Financial rewards, e.g., in the form of a “most efficient user”, the comparison of energy consumption in the form of a ranking and the display of community energy consumption were perceived as stimulating by two thirds of the respondents of
each model. Among all possible elements, the award in the form of a ranking was most often considered to have a positive motivational effect.

The method of communicating the before mentioned information also plays an important role, which is why we have presented all possible ways of providing information to the respondents. They then had the possibility to choose from a list of 5 options. In addition, the respondents themselves could contribute ideas and suggestions. Finally, we asked them to create their preferred order/rank list for the type of communication channel. The frequency distribution of information mediums and rankings can be seen in Figure 14. It is very evident that respondents want to receive their information first and foremost via email. However, some also mention access via a smartphone app or a web portal. We found this for all business models. In second place in the ranking, in addition to the latter, the digital interface is also mentioned slightly. In third place in the ranking, it is apparent that similarly frequent mentions are made across all models and media. An additional digital interface in the house is not desired more than other alternatives. This speaks in favour of concentrating on naming the first and second place.

A further essential component is the frequency with which the information about the content is to be distributed to the customers. Here again, we have provided the possibility of creating a ranking list and various alternatives to choose from. In the first place for all models is the real-time information (Figure 15). This would be the preferred option for the respondents. In the second place, daily, weekly and monthly summaries are desired. In third place, we find monthly and annual information most frequently. It is clear that timely communication of information is of first priority. This contradicts to a certain extent the desire to receive the information via email. The combination of real-time and email is not feasible and suggests that respondents would like to receive a summary of values which are then sent by email. If possible, this should be done monthly or annually, which is actually similar to the usual rhythm of the energy bill. For real-time data, only an additional tool can be used to access the information. Since the respondents do not want an additional interface in the house, the data should be accessible via web portal or app.
<table>
<thead>
<tr>
<th>Evaluation of design elements providing community information by business model</th>
<th>P2P</th>
<th>Volt</th>
<th>DSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information on savings in comparison to other...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information about community (the people who live in...)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information about earnings in comparison to other...</td>
<td></td>
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<tr>
<td>A financial reward which I can receive as the most...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The comparison of my average energy consumption...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The average energy consumption of the community...</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Figure 13.** Frequency of community information motivation evaluations depending on the business model. (DSO N = 59, Volt N = 62, P2P N = 57).
Figure 14. Frequency of the preferred information transfer method depending on the business model. (DSO N = 59, Volt N = 62, P2P N = 57).
The results of the online study show that the business models of two thirds of all respondents are positively accepted. The future models appear to be promising in terms of satisfaction, both for prosumers and consumers. Further conclusions from the results on interface design can be found in the chapter Guidelines.

Figure 15. Frequency of the preferred information frequency depending on the business model. (DSO N = 59, Volt N = 62, P2P N = 57).

2.7 Conclusion of European Online Study Results to Guidelines

The results of the online study show that the business models of two thirds of all respondents are positively accepted. The future models appear to be promising in terms of satisfaction, both for prosumers and consumers. Further conclusions from the results on interface design can be found in the chapter Guidelines.
3 Validation of Online-Survey Results Regarding Gamification Techniques for the Peer-to-Peer Model

The main concern of the focus group was to explore the gamification approach within DER. Validation of the results reported in Chapter 2 is one goal that was reported in the following section. Therefore, we investigated an interface using gamification strategies with potential users, i.e., prosumers and consumers. In addition, we wanted to identify and discuss alternative strategies and underlying motives to those already reported in the literature. The user interface was provided by the project partner Hive Power.

3.1 Motives

Besides cognitive and affective responses when using new systems, users’ engagement is based on the assumption of intrinsic motivation [10], which is defined as the internal motivation to perform an activity for the sake of itself and the pleasure and satisfaction that is derived from performing it. Long-term influences on the behavioral engagement are expected. Gamification [11] uses elements that target the basic pillars of intrinsic human motivation [12], which are postulated in the self-determination theory of motivation [12]. Namely autonomy, competency, and relatedness. Whereas autonomy and competency mechanisms mostly refer to intrinsic motivation, the concept of relatedness applies most often extrinsic tools. Referring to studies in other disciplines, it is becoming more evident that the use of extrinsic strategies alone will not lead to a positive long-term participation. Behavioral strategies to increase autonomy and competence should also be implemented [13]. Autonomy describes in this context a sense of voluntariness that can be associated with any behavior. However, it does not mean objective independence from others. It is rather the subjective feeling of independence. Competence is defined as the feeling of being able to effectively influence what is considered important and to achieve the desired results. Relatedness means not only the importance that others attribute to one, but also the importance that one person has for others. Within the focus groups, we want to identify if and what kind of gamification strategy would be suitable for a user interface in a local energy community. Therefore, the focus groups conducted aimed at contributing to the user-centered design of a self-consumption community scenario. On the one hand, we had the users evaluate a developed user interface of Hive Power for it and on the other hand, the users were asked to express their own ideas. We decided to conduct two separate focus groups, one for pro- and one for consumers as a homogenous group composition is known to facilitate a common basis in the discussion [14].

3.2 Focus group method

A focus group [14] is a type of group discussion in which a moderator leads a discussion with a kind of a handbook. This is similar to a semi-standardized interview but is conducted with a group. The questions are asked in an open format so that each participant can express his or her opinion. The main advantage of the focus group is that ideas can be developed further by being inspired. The presence of a moderator allows the inclusion of
more quiet participants in case of dominance of other individual participants. This, in turn, can allow a diversity of opinions to be expressed. However, it is important to note that focus groups do not have representative results as their ultimate objective. It is much more about discussing and developing ideas in the first stage.

3.3 Sample

A total of 9 people participated in the focus group for consumers, 4 of whom were female. The average age was 50 years ($M = 50.33; SD = 16.60$). The majority (5) stated that they had a university degree as the highest educational level, followed by a doctorate (2). On average ($Mdn = 5.00$) they lived in a city with "100,000 to 500,000" inhabitants. The prosumer focus group was conducted with 7 participants, one of whom was female. The average age was 48.00 years ($SD = 12.22$). Here, too, the majority had a university degree (6), followed by one participant who indicated an apprenticeship. The residence of the prosumers also had an average of "100,000 to 500,000" ($Mdn = 5.00$) inhabitants. Self-assessed knowledge about renewable energies was rated higher by prosumers ($M = 4.14$, "slightly agree"; $SD = 0.86$) than by consumers ($M = 3.85$, "slightly agree"; $SD = 0.67$). With regard to the self-assessed knowledge of network stability, we see similar results (consumer: $M = 3.00$, "slightly disagree", $SD = 1.11$; prosumer: $M = 3.29$, "slightly disagree", $SD = 0.80$). The prosumers consider themselves to have a high affinity for technology ($M = 4.65$, "largely agree "; $SD = 0.73$) while the consumers were more in the range of the standard values.

3.4 Procedure

We sent out focus group notifications via email to the participant panel of our research group. In the invitation mail we have defined the description of the user groups relevant for the focus groups. Prosumers are "people, who produce electricity themselves, e.g. with a

![Figure 16. Focus group participants during assessment of information needs.](image-url)
photovoltaic plant”. Consumers are “people, who purchase electricity”. The final invitation included a topic introduction and a description of the self-consumption scenario (Annex 1). In the beginning, the participants were asked to sign the consent form and a demographic questionnaire was handed (including age, gender, level of education, size of the city, or place of residence). We asked the prosumers additional questions about their energy plant. Everyone received a briefing on the NEMoGrid research project [15] and the scenario. Next, we questioned potential advantages and disadvantages of the scenario and the desired information of the pro- and consumers in such a scenario in an open format. Keywords from the participants’ statements were listed and placed on the table. After that, we asked the test participants to rate the importance of all mentioned information. For this we handed out 3 red, green and yellow sticky dots (red = "I personally do not need this information.", yellow = "That’s good to know, but I’m sure I just check in every once in a while", green = "Very important, I always want to have quick access to this information"). After the evaluation, we gave the prosumers and consumers the opportunity to discover a developed platform (web interface) themselves for about 5 minutes. Subsequently, the participants were given a usability questionnaire to evaluate the interface. The System Usability Scale (SUS, [16]) provides a “quick and dirty”, reliable instrument for measuring usability. It consists of 10 items with five response options for respondents; from “Strongly agree” to "Strongly disagree". To ensure that all participants had the same understanding of this platform, we conducted a guided exploration. Subsequently, we concentrated on the implementation of other gamification concepts. Pro- and consumers should individually complete three different sentences: 1. “To strengthen my competence in dealing with energy, I would like, within the framework of my self-sufficient energy community, that...”; 2. “To strengthen my feeling of solidarity with other energy producers and consumers in my self-sufficient community, I would...”. Finally, the participants briefly presented their best idea to the group. Each participant received a remuneration of 50 € (about 55$). The maximum duration was 2 hours.

3.5 Data Analysis

At first, we report the results of the usability evaluation. Explanations for the task, in which the participants had to complete the sentences, were digitalized, itemized into statements, categorized, if necessary shifted to other approaches or deleted (if not understandable), and counted. Results are reported on statements made by more than one person. For the most frequently mentioned categories, the following quotations are given as examples.
Acceptance & Usability

The total score of the usability evaluation with the SUS was: $M = 67.12$ ($SD = 14.66$), which corresponds to a rather good evaluation. Differences between prosumers and consumers are not visible.

After the exploration, we wanted to know what the test persons would want to retain in the solution and whether they had suggestions or needs for changes. During the demonstration of the platform, consumers generally praised the platform as functional and clear. With regard to user-friendliness with the smartphone, there was predominantly positive feedback. One participant remarked that the graphics are difficult to grasp but would be easier to understand in landscape format. Consumers criticized above all the menu items on financial merit. Here they would like to see a “balance” display in the graphic and the table excerpts. The handling of the time aggregated overviews turned out to be difficult on the smartphone, because a less accurate selection of data is possible here. During the demonstration of the platform in the prosumer group, significantly more aspects of the platform were questioned and criticized. One participant stated that he/she expected more interactive functions than purely descriptive evaluation graphics. It was again noted that “balance” information was missing in the price information. It was also mentioned that the colour for price graphics for energy purchases (orange) is very similar to the colour for energy obtained from the grid. This could lead to misinterpretations. With regard to the energy consumption graph, it was noted that the feed-in shown “to Community” below the 0-point and the consumption information “from Grid” above the 0-point is felt to be counterintuitive. During the demonstration, it was also checked whether the data under the menu item “My Energy” refers to the individual household or to the entire community.
Competency

From consumers we received 8 categorizable statements for the concept of competence, which were focused on "offering topic-related learning" (3), "making expert knowledge accessible" (2), and "giving recommendations for behavior" (2). Among the prosumers, 7 statements were written down. Three of the statements referred to "making electricity related information accessible" (3), and two mentioned "making expert knowledge accessible" (2). Competence-based ideas were hardly discussed in the group. One participant mentioned that as much as possible (e.g. with regard to installation) should be taken away from the users. The ongoing effort for participants in the P2P scenario would have to be kept as low as possible.

“All participants are trained so that all have the same level of knowledge.”
(subject 6; competence, topic-related learning)

“...clearly shows what’s happening. (→ Production, withdrawals, various Producers displayed, various consumers and their consumption behaviour in the community); also external reference and its parameters”
(subject 12; competence, making electricity related information accessible)

Autonomy

From the consumers, we received 5 categorizable statements for the concept of competence, among which the most important was the securing of the energy supply. The autonomy approach was discussed less in the group. Autonomy related objections were mentioned as a counter-argument to ideas on the topic of connectivity. For example, one person mentioned that a change of fellowship should also be made possible for him or her. Another consumer made it clear that he/she did not need a community in terms of electricity consumption and that supply was the main issue here. Among the prosumers, 7 statements were written down. The main objective here was on: "reducing bureaucratic hurdles" (2), and "creating individual control/influence possibilities" (2). The participants emphasized that they highly appreciate self-determination with regard to energy supply (which is already being granted). This should continue to be possible.

“Attach importance to functioning delivery!”
(subject 1; autonomy, supply security, guarantee)
Relatedness

We received 9 categorizable statements from the consumers. Here it was talked about actually offering "physical community activities" (4), and "enabling exchange with others" (2). Participants expressed that creating or maintaining a sense of community is considered central to this concept. This could be achieved, for example, by information that creates a positive image of the community. However, the formation of a community is also seen as the biggest hurdle, because one has to rely on others and get involved. The organization of coordination processes, e.g. about joint investments, is seen as an important decision hurdle. Among the prosumers, 7 statements were also written down. Like the consumers, "physical community activities" (3) were mentioned, but also the "formulating common objectives" (2) was ordered. Social activities that reduce anonymity in the consumer community were discussed. The participants considered it interesting to get to know the other consumers and producers personally and to promote the exchange among them. During the discussion, it was emphasized that fairness within the consumer community should be observed.

"...we meet at least 1x/ month."
(subject 3; attachment assigned, physical community activities)

"meet with the others"
(Subject 17; attachment assigned, physical community activities)

3.6 Conclusion

Regarding the platform, we found that it was average user friendly, functional and clear. Participants see improvements in the color scheme and alignment of prosumer chart information. Approaches that promote connectedness with others were considered central by pro- and consumers. Social activities were discussed in particular. For consumers, building competence, e.g. through access to expert knowledge, is also important. With regard to autonomy-promoting approaches, the preservation of self-determined decisions in both groups was mentioned.
### 4 Guidelines for User-Centered Development of Approaches for Enhancing Social Acceptance and User Collaboration

For the integration of users and the increase of motivation to participate in one of the business models, we have compiled the following recommendations for the design of interfaces.

Users should receive both personal, grid-related and community information.

The presentation of information such as:

1. the personal savings,
2. personal earnings,
3. the average consumption and
4. the change of consumption over time

are desirable and increase the competence as well as grid information. Here information such as:

1. critical grid situations,
2. grid stability information and
3. the demand for balancing the grid

should definitely be reported.

Personal earnings and savings comparisons between individual users and the community are not considered very motivating and should therefore be avoided.

However, tools that present connectedness in a rather privacy-secure way, such as the financial reward as the most efficient user, can have a motivating effect.

Comparisons of one's own consumption in relation to the community and the average energy consumption of the entire community are also rated very motivating. Therefore, we recommend including these three concepts in order to establish a kind of relationship between the users.

Create offers for concepts that promote solidarity for all users of the participating community. These offers can also exist in social/physical form, for example at a kind of regulars' table.

For consumers, building competence, e.g. through access to expert knowledge, is important. Provide consumers with expert knowledge.
The assurance of self-determination is very important for both prosumers and consumers and should definitely be emphasized within each model.

As far as the results allow, it can be deduced from the way information is communicated that both emails and a web portal are a good interface for users. Emails should rather contain a summary of the consumption of the last week, months while real-time data on the web portal is a good way to increase the sense of competence.
5 ANNEX

5.1 BUSINESS AS USUAL (PROSUMER) – LOAD CONTROL APPLIED

...you mainly retrieve your electricity from your own PV plant installed at your house. Further, there is a smart meter installed in your household. Initially, you paid the PV plant and network infrastructure installed in your household. However, you always have the possibility to retrieve electricity from the DSO, since you are connected to the grid. Additionally, you have a personal energy storage (battery) at your house from which you can take energy.

In general, loads of every energy pro- and consumer, who is connected to your grid are controlled with a specific time schedule (operationalized via simple algorithm), applied by the DSO, to control your load in dependency of the overall grid situation. This time schedule ensures, that your energy consumption will be shifted to another time period when grid prices are lower (e.g., day=high tariff and night time=low tariff). This shifting could be done by e.g. rescheduling activities, switching off unnecessary appliances or switching to your installed storage (battery) from which energy is then consumed. So, in case the DSO decides to turn off appliances from your household due to peak periods of electricity consumption in the grid, you are always falling back on self-consumption or your storage.

There is a monthly bill that is made up of three components.

- First of all, you pay for your quota of network services usage (transmission and distribution of electricity) and the time schedule (simple algorithm), that is used in order to control your loads.

- Second you pay for the electricity that was consumed by your household. The tariff for the network service and the electricity is static, meaning there are a day and a night tariff.
  - In case you consume, what you are producing you don't have to pay anything. If anything, you benefit from a reduction in transmission and distribution costs on the side of the network.
  - In case you produce more than you need, you feed in the surplus into the grid and the responsible DSO applies a static Feed-in Tariff (FiT). Hence, you benefit from feeding in energy.
  - The last component that needs to be paid is the storage facilities installed at your household. This storage can be either leased or owned. In case of ownership of the storage, monthly rates are dropped.
  - Due to load shifting to a time period in which prices are lower, you “save” money. Additionally, you will benefit from not using the network services at time periods when loads are very high. You use the storage you bought to increase your self-consumption and therefore additionally reduce your bill.

Costs for the algorithm applying the time schedule and storage are supposed to be smaller than savings resulting from the techniques.
5.2 **BUSINESS AS USUAL** (**PROSUMER**) - **NO LOAD CONTROL**

...you produce your own energy from the PV plant installed on your roof. Initially, you paid the PV plant and network infrastructure installed in your household. If you consume what you are producing, you don’t have to pay the energy quota to the retailer. In case you produce more than you need, you will feed in the surplus into the grid. Therefore, you will get a financial incentive (feed-in tariff) by your DSO (Distribution System Operator). In case you produce less energy, you could also retrieve energy from your DSO. Here, the tariff you pay is very static: probably you have a fixed price for one kWh during night and daytime, which is applied. Depending on how much energy you consumed you have to pay a quota related to network services (transmission and distribution), and taxes. Consequently, your monthly energy bill depends on your production and consumption ratio and on your night/day consumption profile.

Your role: pay your energy bill.

5.3 **BUSINESS AS USUAL** (**CONSUMER**) - **NO LOAD CONTROL**

...you retrieve your energy from your DSO (Distribution System Operator) and pay a monthly bill depending on how much energy you consumed, and a quota related to network services (transmission and distribution). You have a fixed price for one kWh at day time and a fixed price at night time for the energy you consume. You don’t have any additional infrastructure installed, there is just a meter capturing your consumption. Consequently, you don’t have any additional costs. You have the possibility to save money by reducing your consumption. If you don’t reduce your consumption, your energy bill usually stays the same compared from one month to the month of the previous year.

Your role: pay your energy bill.

5.4 **BUSINESS AS USUAL** (**CONSUMER**) - **LOAD CONTROL APPLIED**

...you retrieve your energy from your DSO (Distribution System Operator). Further, you have a smart meter installed in your household. A time schedule (operationalized via a simple algorithm) is applied by the DSO, to control your load in dependency of the overall grid situation. The time schedule ensures, that your energy consumption will be shifted to another time period when grid prices are lower (e.g., day [high tariff] and night time [low tariff]). This shifting could be done by e.g. rescheduling activities or switching off unnecessary appliances (e.g., water heaters).

There is a monthly bill that is made up of two components.

- First of all, you pay for your quota of network services usage (transmission and distribution of electricity) to the DSO and for the time schedule that is used in order to control your loads.
- Secondly, you pay for the electricity that was consumed by your household. The tariff for the network service and the electricity is static, meaning there is a high and a low tariff.
Due to load shifting to a time period in which prices are lower, you “save” money by not paying the high peak prices. Additionally, you will benefit from not using the network services at time periods when loads are very high and energy expensive.

Your role: pay your energy bill. The DSO will provide you the algorithm and the storage facility, charging the additional cost in the network component part of your tariff.

5.5 DSO Planned (Consumer)

...you retrieve your electricity from your DSO (Distribution System Operator). The DSO controls loads of every energy pro- and consumer, who is connected to your grid, directly with a specific algorithm. The algorithm ensures, that your energy consumption will be shifted to another time period when prices are lower (e.g., night time). This shifting could be done by e.g. rescheduling activities, switching off unnecessary appliances or switching to a storage from which energy is then consumed. This energy storage (battery) is linked to a pool of users and charged during times of energy surplus. So, in case the DSO decides to turn off appliances from your household due to peak periods of electricity consumption in the grid, you are always falling back on this shared storage. If there is an electricity gap (no energy in storage) you retrieve energy from the DSO for a retail price. However, the DSO centralized algorithm also manages the storage facilities. There is a fixed storage capacity used as an electric buffer for peak shaving and other ancillary services in LV (low voltage) grid.

There is a monthly bill that is made up of three components.

- First of all, you pay for your quota of network services usage (transmission and distribution of electricity).
- Secondly, you pay for the electricity that was consumed by your household. Due to the load control usage, the tariff represents a discounted rate (which is usually flat) for network service as well as the electricity.
- The last component that needs to be paid is the shared storage facilities. This storage can be leased. Therefore, monthly costs arise.

By allowing the DSO to manage your loads and storage facilities, the DSO is able to balance the grid, which in turn has the benefit of rather flat energy and network costs for you. Savings out of decentralized direct load control are supposed to be higher than additional costs for the storage.

Your role: pay your energy bill including storage facilities. The DSO manages your load profile.

5.6 DSO Planned (Prosumer)

...you mainly retrieve your electricity from your own PV plant installed at your house. However, you always have the possibility to retrieve electricity from the DSO, since you are connected to the grid. Additionally, you have an energy storage from which you can take energy. This energy storage is charged in times of energy surplus (produced by your PV). In general, the DSO controls the loads of every energy pro- and consumer, who is connected to your grid with a specific algorithm. This algorithm ensures, that your energy consumption
will be shifted to another time period when prices are lower (e.g., night time). This shifting could be done by e.g. rescheduling activities, switching off unnecessary appliances or switching to an onsite installed storage from which energy is then consumed. So, in case the DSO decides to turn off appliances from your household due to peak periods of electricity consumption in the grid, you are always falling back on the storage. If there is an electricity gap (no energy in storage) you retrieve energy from the DSO for a retail price. However, the DSO centralized algorithm also manages the storage facilities. There is a fixed storage capacity used as electric buffer for peak shaving and other ancillary services in the LV (low voltage) grid.

There is a monthly bill that is made up of three components.

- First of all, you pay for your quota of network services usage (transmission and distribution of electricity).

- Secondly, you pay for the electricity that was consumed by your household. However, you are allowing the DSO to control your consumption, which is incentivized monthly. Generally, due to decentralized direct load control usage, the tariff represents a discounted rate (which is usually flat) for network service as well as the electricity. If you consume the electricity you generated with your own PV, you pay a “Levelized Cost of Electricity” (LCOE). The LCOE can be regarded as the average minimum cost at which electricity must be sold in order to break-even over the lifetime of the project.

- The last component that needs to be paid is the storage facilities installed at your household. This storage can be either leased or owned. In case of ownership of the battery, monthly rates are dropped.

By allowing the DSO to manage your loads and storage facilities, the DSO is able to balance the grid, which in turn has the benefit of rather flat energy and network costs for you. Savings out of decentralized direct load control are supposed to be higher than additional costs for the storage.

Your role: pay your energy bill including storage facilities. The DSO manages your load profile.

5.7 Voltage-Tariff (Consumer)

...you mainly retrieve your electricity from your DSO (Distribution System Operator). Further, there is an algorithm that is used to fix local congestion problems minimizing, on the one hand, the overall costs of energy on the basis of your preferences and on the other hand supporting the grid. A preference could be to have your laundry done by tomorrow morning or within the next hour. The algorithm then shifts your loads (doing the laundry) with the main goal of minimizing your monthly bill. So, laundry will be done in times of low local congestion, when costs are rather low. Savings are -more or less- incentives from the DSO for supporting the grid. These incentives can be achieved by allowing the aforementioned algorithm to shift your loads in the grid from peak-times to off-peak times in times of high loads. If there is an electricity gap you will retrieve energy from the DSO for a retail price.

The tariff is not constant and varies depending on the local state of the grid: low voltages correspond to a high grid load and therefore to high prices for consumption; high voltages
correspond to low grid load and therefore to low prices for consumption. The price depends on the actions of all the neighbors and on the location on the grid. There is a monthly bill that is made up of three components.

- First of all, you pay for your quota of network service usage (transmission and distribution of electricity).
- Secondly, you pay for the ratio of electricity that was consumed by your household from the grid.
- In case you consume from the grid you have to pay a grid tariff, which is depending on the actual voltage status (high voltage= low costs, low voltage= high costs) of the grid.
- The DSO could have higher profits due to load management service, therefore a profit-sharing policy between consumers and DSO could be agreed on.
- At least you have to pay for the algorithm which minimizes your costs against the dynamic grid tariff and simultaneously fixes local congestion problems on the basis of the grid status.

By allowing the algorithm to manage your loads, peak consumption can be avoided, which in turn has the benefit for you to avoid extra costs and receive a bonus for off-peak consumption and for the grid status.

Your role: pay your energy bill, including additional quotas for algorithm and storage facilities.

5.8 Voltage-Tariff (Prosumer)

...you mainly retrieve your electricity from your own PV plant installed at your house. Initially, you paid the PV plant and network infrastructure installed in your household. However, in case of an “electricity gap” you always have the possibility to retrieve electricity from the DSO since you are connected to the grid. Additionally, you can take energy from your storage, which is also linked to a pool of users and the grid, in case your PV did not produce enough energy to meet your demands. This energy storage is charged with the surplus you produced.

Further, there is an algorithm (applied via a dedicated smart meter) that minimizes your costs and simultaneously fixes local congestion problems on the basis of the grid status, your preferences and the PV excess valorization options. A preference could be to have your laundry done by tomorrow morning or within the next hour. The algorithm then shifts your loads (making the laundry) with the main goal of minimizing your monthly bill. For example, laundry will be done in times of low local congestion, when costs are rather low. If you consume energy from the grid/DSO you pay a tariff that is not constant. The tariff varies depending on the local state of the grid: low voltages correspond to a high grid load and therefore to high prices for consumption; high voltages correspond to low grid load and therefore to low prices for consumption. The price depends on the actions of all the neighbors and on the location on the grid.

When injecting energy, you also have to pay according to the tariffs because you are using the network infrastructure. However, this fee is reduced compared to purely consuming.
energy, due to the fact that you receive compensation for the injected energy. In case of an "electricity gap" you retrieve energy from the retailer/DSO for a retail price. There is a monthly bill that is made up of four components.

- First of all, you pay for your quota of network service usage (transmission and distribution of electricity) for consuming and injecting energy.

- Secondly, you pay for the ratio of electricity that was consumed by your household from the grid deducting the costs of electricity that you fed into the grid by at a certain time.
  - If you consume the electricity you generated with your own PV, you pay a "Levelized Cost of Electricity" (LCOE). The LCOE can be regarded as the average minimum cost at which electricity must be sold in order to break-even over the lifetime of the project.
  - In case you consume from the grid you have to pay a grid tariff, which is depending on the actual voltage status (High voltage= low costs, Low voltage= high costs) of the grid.
  - In case you feed in energy you will receive a retail price for the energy according to the grid tariff. You will always have to pay for the network service usage when injecting. However, the bonus you receive for the feed in energy is higher than the network service usage.

- The third component that needs to be paid is the storage facilities installed at your household. This storage can be either leased or owned. In case of ownership of the battery, monthly rates are dropped. In case of leasing, costs could be reduced by a discount for allowing the DSO to keep a certain percentage of the storage capacity to use freely to its needs.

- At least you have to pay for the algorithm which fixes local congestion problems on the basis of your preferences and PV excess valorization options.

By allowing the algorithm to manage your loads and storage facilities, peak consumption could be avoided, which in turn has the benefit for you to avoid extra costs and receive a bonus for off-peak consumption. Savings out of grid tariff control are supposed to be higher that additional costs for the battery/storage.

Your role: pay your energy bill, including additional quotas for algorithm and storage facilities.

5.9 P2P (Peer-to-Peer; Consumer)

...you mainly retrieve your electricity from your local grid you are connected to. You will create a self-consumption community (SCC) with your neighbors seen as a single entity by the DSO. Inside the SCC you can trade energy with your neighbors at prices that are better than those of the DSO. Further, there is a smart meter installed at your household and a storage to which you and a pool of users (neighborhood) are linked to. This storage is leased by the DSO.

The main scope lies in trading excess energy with your neighbors. The trading mechanism is automated thanks to an algorithm realizing a double auction mechanism. When buying energy, you as buyers submit a bid to an auctioneer for the energy a prosumer wants to sell. At the same time, the seller also submits an offer for the price he wants to sell his energy for. Trades are handled using the blockchain. A blockchain is a distributed database that maintains an ever-growing list of transactions. The database is extended.
chronologically linearly, similar to a chain, at the lower end constantly new elements are added (hence the term “block chain”). If one block is complete, the next one is created. Each block contains a checksum of the previous block.

The prices for energy in the local market are lower than the real-time price rates in the high voltage grid. Nevertheless, you can still retrieve energy from the grid. There is a monthly bill that is made up of five components.

- First of all, you pay for your quota of network services usage (transmission and distribution of electricity).
- Secondly, you pay the price you offered in all the double-blind auction for electricity that you consumed. The money you pay is lower than a real-time price rate for electricity. Costs for transmission and distribution of P2P trade electricity are exempted. You can always retrieve energy from the grid, but this is more expensive.
- The third component that needs to be paid is the storage facilities. This storage can be either leased or owned. In the case of ownership of the battery, monthly rates are dropped. In case of leasing, costs could be reduced by a discount.
- Further, you have to pay for the algorithm which fixes local congestion problems on the basis of the double-blind auction and offers the possibility of retrieving cheaper energy.
- At least you have to pay for the P2P management carried out by the DSO.

By locally trading the energy transmission charges are on a discounted rate. There are costs for P2P management algorithm. However, the costs are lower than the overall gains. The advantage for the consumer is that you can buy the energy from a prosumer for a lower price than the grid price from the DSO if you are a flexible consumer.

Your role: pay your energy bill, including additional quotas for storage and algorithm.

5.10 P2P (Peer-2-Peer; Prosumer)

...you mainly retrieve your electricity from your own PV plant installed at your house. You will create a self-consumption community (SCC) with your neighbors seen as a single entity by the DSO. Inside the SCC you can trade your produced energy with your neighbors at prices that are better than those of the DSO. Initially, you paid the PV plant and network infrastructure installed in your household. Further, there is a smart meter installed at your household. Additionally, there is a storage for a pool of users leased from the DSO. This energy storage is charged with the energy surplus from your PV.

However, the main scope lies in trading excess energy with your neighbors. The trading mechanism is automated thanks to an algorithm realizing a double auction mechanism. When selling energy, you as a prosumer submit your asked price for the energy at the same time as the buyers submit a bid to an auctioneer. Trades are handled using the blockchain. A blockchain is a distributed database that maintains an ever-growing list of transactions. The database is extended chronologically linearly, similar to a chain, at the lower end constantly new elements are added (hence the term “blockchain” = “block chain”). If one block is complete, the next one is created. Each block contains a checksum of the previous block.
In general, the price paid for the PV excess you produced is higher than real-time price rates and a Feed-in-Tariff (FiT). FiT means feeding energy into the DSO grid. Further, the PV excess price is more attractive than self-consumption. The difference between the export price and the “Levelized Cost of Electricity” (LCOE) is your revenue. The LCOE can be regarded as the average minimum cost at which electricity must be sold in order to break-even over the lifetime of the project.

The DSO takes care of the P2P market administrative management.

There is a monthly bill that is made up of five components.

- First of all, you pay for your quota of network services usage (transmission and distribution of electricity). However, there is a discounted tariff for your quota of P2P usage.

- Secondly, you pay for the quota of electricity you retrieved.
  - If you consume the electricity you generated with your own PV, you pay a “Levelized Cost of Electricity” (LCOE). The LCOE can be regarded as the average minimum cost at which electricity must be sold in order to break-even over the lifetime of the project.
  - In case you trade the PV excess, the price you earn depends on the double-blind auction. However, the money you receive is higher than a Feed-in-Tariff or the real-time price rate for electricity. Costs for transmission and distribution of P2P trade electricity are exempted.
  - You can always retrieve energy from the grid, but this is much more expensive.

- The third component that needs to be paid is the storage facilities. This storage can be either leased or owned. In case of ownership of the battery, monthly rates are dropped. In the case of leasing, costs could be reduced by a discount.

- Further, you have to pay for the algorithm which fixes local congestion problems on the basis of your PV excess and the double-blind auction.

- At least you have to pay for the P2P management carried out by the DSO.

By locally trading the energy transmission charges are on a discounted rate. There are costs for P2P management algorithm. However, the costs are lower than the overall gains. The advantages for the prosumers are that they sell their excess energy at a higher price to a flexible consumer than to the DSO. You can reduce the payback time of your PV and batteries, lowering their "Levelized Cost of Electricity" (LCOE). The LCOE can be regarded as the average minimum cost at which electricity must be sold in order to break-even over the lifetime of the project.

Your role: pay your bill, including additional quotas for storage and algorithm.
REFERENCES


empirical social science: from conception to evaluation]. Wiesbaden: Springer. doi: 10.1007/978-3-531-19397-7

