Do it yourself - PV for everybody!

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***Abstract*—This paper describes the planning, implementation and evaluation of a series of workshops about the application of photovoltaic technologies in private households. The spread of PV technologies is growing rapidly, arousing the interest of many people who have no previous experience with them [1]. The goal of the workshop series is to show interested people the various possibilities of PV technologies in their own households in theory and practice in order to create a deeper understanding of this technology and its chances in the society. In order to address as broad a spectrum as possible, three different topics were developed for the series: off-grid PV systems, balcony power plants and possibilities for setting up your own solar power system on flat roofs. To be able to draw conclusions from the workshops, a survey was conducted among the participants at the beginning of the workshop and after about four weeks. The results are also presented and interpreted in this paper. In addition to this paper there is a poster presentation about these workshops as well as a manual explaining the exact process of the whole workshop so that it can be continued by other students.**

***Keywords*—PV, workshop, balcony power plant, off-grid PV, flat-roof PV**

I. Introduction

The use of photovoltaic systems in private households can have a meaningful contribution to the green energy transition and provide an increasing independence from rising energy costs for users [1]. In the process, various more specialized applications of PV technologies, including PV balcony power plants and PV island systems, are developing alongside the classic PV systems on the roof of the house. These technologies offer the potential to make renewable energy accessible in different environments and for different purposes. The workshop aimed to increase knowledge about these technologies and get the participants to try out by assembling PV systems themselves. To understand the effects of the workshop on the participants, a survey was conducted before and four weeks after the workshop.

After the planning of the three different workshops in the second chapter, the implementation of each workshop topic is explained individually in the third chapter. Finally, the results of the workshop surveys are evaluated and conclusions are drawn.

II. Planning of Workshops

A. Content of the Workshops

The workshops consist mainly of two parts, a theoretical part, in which the basics of PV technology, legal hurdles and financial aspects are explained and a practical part on the terrace of the university, in which the participants can directly try out the knowledge gained. After determining which member of the workshop-team is responsible for which topic, presentations are designed for the theoretical part in order to explain the contents as clearly as possible. Additionally, concepts for the practical part are being developed. The maximum number of participants for each workshop is approximately 20. This ensures that each supervisor can support four to five participants during the practical part of the workshop, allowing them to engage with the material independently.

B. Advertisement of the workshops

At first it is decided how the workshops could be advertised to reach as many people as possible. Since the target group is mainly the general public, it is the goal to advertise as widely as possible. For this purpose, various associations in the area of Cologne that deal with PV technology are being contacted. In addition, every employee and student at the university and employees of the city Cologne are being contacted via e-mail. Advertising is also done via social media channels of the university, local associations and a regional energy transition influencer. People interested in the workshop series should register by e-mail without obligation, so that the approximate number of participants can be estimated.

C. Procurement of materials

For the practical part of the workshop, many different materials are needed, including PV modules, inverters, cables, batteries, mounting systems and power measurement devices. For this purpose, different regional companies and associations are being contacted. As a result, many old PV modules in different sizes have been given, mostly free of charge. The remaining materials had to be purchased.

III. Implementation

In the following, the implementation of the workshops, structured in the three different topics, will be explained.

A. *Balcony power plants*

Balcony power plants are small individual PV-systems with a micro inverter that can easily be connected to the house power grid by plugging them into the power socket. Since such a system consists of only one or two solar panels, it can be flexibly mounted on a house wall, on a balcony or even on a garage. In order to demonstrate these possibilities, modules, inverters as well as mounting systems are presented in the practical part. The systems are currently limited to a maximum power output of 600 W, but if they are placed in a sunny spot, they can generate a non-negligible proportion of electricity that can be consumed directly through the household grid. However, the electricity generated cannot be remunerated. If it is not consumed directly, it is fed into the grid and thus given to the public. Nevertheless, electricity costs can be significantly reduced and a system often pays for itself after a few years. Because of that and because the systems can easily be assembled and connected without the need of a professional electrician, the interest in balcony power plants has increased significantly in recent years.
Since there are currently many legal things to consider and new regulations will apply in Germany from 2024, there is a lot of uncertainty among the participants. Therefore, the theoretical part will also present the legal hurdles [2].

Figure 1: Practical part balcony power plants

As shown in the picture, the PV module is screwed onto the mounting system, connected to the inverter and plugged into the socket. Simple power measurement devices that are plugged into the power socket show the currently produced power output of the system. By tilting or intentional shading of the modules differences in the power output can instantly be seen.

B. *Off-grid solar systems*

PV-off-grid systems are systems that have no connection to the electricity grid and are therefore self-sufficient. They are used for applications where a connection to the grid is not practical or possible and the power demand is not too high, for example in a remote garage or in a garden. Typically, a 12 V or 24 V battery is used to guarantee a permanent power supply. To ensure that the battery is not damaged during charging and discharging, a charge controller is also connected. The other components are PV modules, an inverter and cables.

Unlike balcony power plants or rooftop solar systems, off-grid PV systems do not directly save electricity costs, so it is not possible to estimate the exact return on investment. There are currently some complete packages available on the market that include all the main components. However, to save some money, you can build your own system.

Figure 2: practical part off-grid solar system

In the practical part of the off-grid workshop, participants can assemble the components themselves under supervision. As this is more complex and mistakes can be made when connecting, a supervisor will check this before connecting to the battery. In a 12 V system, a possible electric shock is not as dangerous as in the general power grid, but short-circuiting the battery is to be urgently avoided. The participants can then connect various consumers with 230 V to the inverter or with 12 V directly to the charge controller. The focus of the participants' interest is especially on the required components, such as the charge controller and the batteries, as there are many different things to consider depending on the battery type.

C. *Self installation of rooftop solar system*

The third part of the workshop series deals with the self-assembly of PV systems on one's own roof. As this becomes dangerous above a certain roof slope and requires special fuses, this is only suitable for flat roofs. The focus of this workshop is on the mounting of the PV modules, as an electrician is required to connect the entire system to the power grid. There are many different possibilities for the installation of the solar modules. These will be presented in this workshop. In the practical part, a special mounting system will be presented on the roof and installed by the participants.

Figure 3: theoretical part of workshop about self-assembly

In the workshop about the possibilities for self-assembling a PV-system, the focus of the participants is on the mounting options for the PV modules and their safety regarding the effects of strong winds and the maximum static load on the roof.

IV. Survey

In order to determine the impact of participating in a workshop of the series, a survey will be created for participants to answer at the beginning of the theoretical part of each workshop. After about four weeks, a second survey will be sent out to the participants by e-mail. Depending on the topic of the workshop, the questions are specifically adapted, but the key content of the question remains identical.

A. Questionnaire

In the first questionnaire, the participants are asked nine questions. The purpose is to ask about the reason for participating in the workshop and possible previous knowledge about PV technology. The previous knowledge is weighted from "no experience" to "professional" and the source of the knowledge is being assessed. Furthermore, the participants are asked to estimate whether they think if they are currently competent enough for setting up their own balcony/off-grid/flat-roof solar system. In addition, reasons for the acquisition of a solar system, why no acquisition has been made yet and the probability of an acquisition in the near future are asked. Finally, the participants' housing situation is asked in order to draw possible conclusions from the answers in the evaluation.

In the survey, which is being conducted four weeks after the workshop, some questions are changed so that the impact of attending the workshop can be determined. The participants are asked whether they have bought a balcony/off-grid/flat-roof solar system in the last four weeks. Depending on the answer the participants are asked to explain the reasons for or against the purchase of a solar system. In addition, the attendees should explain what they gained from the workshop and how they evaluate the entire workshop.

B. Evaluation

The significance of the results presented in the following are strongly dependent on the response rate of the second survey. Unfortunately, not all participants answered the after-effect survey four weeks after the workshop date, so that the amount of data is not satisfactory for a detailed evaluation.

The first two workshops on the topic of off-grid solar systems were attended by ten people on the first date for the workshop and by eleven people on the second. The survey after four weeks was only answered by six people in each case. The two workshops on self-installation of flat-roof PV-systems were attended by eleven and five people and in total there were only 4 responses to the second survey. For the workshops on balcony power plants, 16 and 5 people came, of whom eleven filled out the second survey. Several additional workshops were offered on this topic on two consecutive days, which were attended by a total of 114 people. Of these, 59 answered the additional survey, so that a total of 135 people attended the workshop on balcony power plants and 70 completed the additional survey.

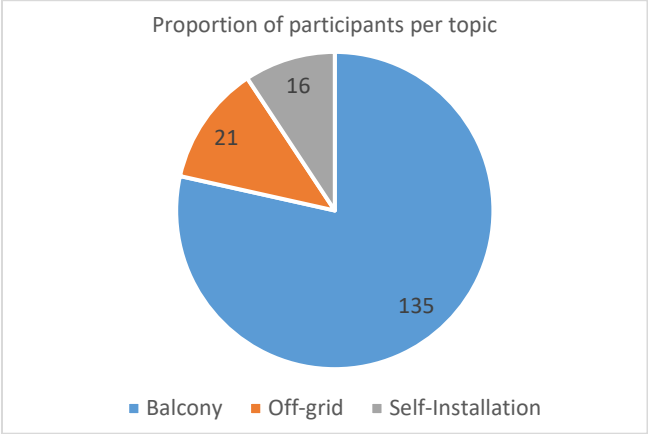

Figure 4: proportion of participants per topic

The entire workshop series was attended by 172 participants, of whom 86, which corresponds to exactly 50%, completed the second survey. Due to the relatively low response rate, the following interpretations of the survey results should be treated with caution.

V. Results

In the following chapter, the results of the balcony power plant workshop are discussed in detail. The results of the other two topics are not considered, as the number of responses after four weeks is too low and therefore no conclusions can be drawn from the answers of the surveys.

Over 80 % of the participants stated that the main reason for purchasing a solar system is to contribute to a sustainable energy transition. From the responses, it appears that at least three people bought and built a balcony power plant within four weeks after the workshop. If this can be attributed to the attendance of the workshop cannot being said unequivocally.

The likelihood of acquiring a plant in the near future, however, has nearly stayed the same. This may be due to the fact that the average interest of the participants in buying a solar system is already relatively high. Therefore, no statement can be made about the change of probability for a new purchase.

The assessment of the own PV knowledge, rated on a scale from 0 to 10, has increased around 73,5 % from 3,86 to 6,70, as you can see in figure 5. This is a strong improvement, which can also be seen in the feedback given by the participants about the workshop contents.

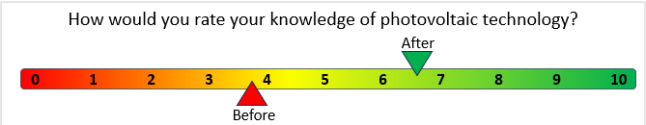

Figure 5: How would you rate your knowledge of photovoltaic technology?

The improved PV knowledge is also reflected in the answers to competence to build an own system. The amount of people who answered with "yes" increases very significantly around 53 % from 60 % to 92 % as it can be seen in the following figure.

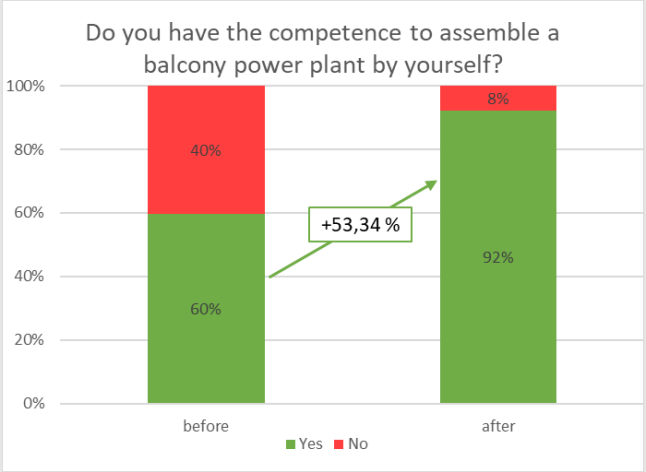

Figure 6: Do you have the competence to assemble a balcony power plant by yourself?

To see possible correlations between the housing situation and the feasibility to get a solar power plant, the attendees were also asked about their current living situation. Because many participants are students, the rate of living for rent is relatively high. Because of difficulties with the landlord, you may not be allowed to build a solar system as a tenant, or you may simply not have enough space in a rented flat.

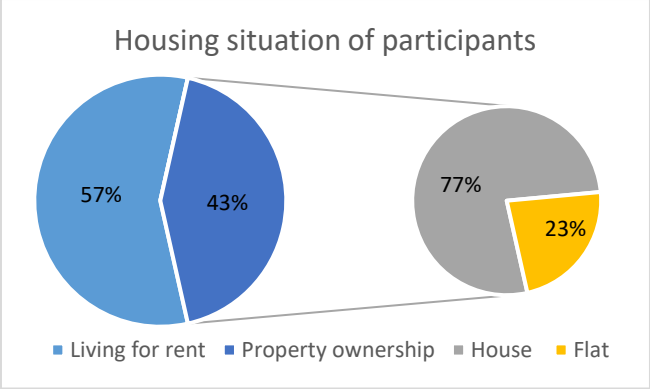

Figure 7: Housing situation of participants

In the pre-workshop survey, 44 of the 135 participants cited lack of expertise as the reason for not having a balcony power plant. This was the most common reason given compared to the other answers. After the workshop, none of the 68 participants cited lack of knowledge as a reason for not buying. This clearly shows that the knowledge imparted in the theoretical part and the direct implementation in the practical part could provide the participants with a basic knowledge.

The workshop was rated very high by the participants. On a scale of 1 to 5, an average of 4.77 was given. One of the main points learned in the workshop was how easy it is to set up and operate such a system. This was also taught directly through the practical part. The overview of current and future legal regulations also provided a lot of transparency and was praised several times.

VI. Concluding Evaluation

In the following a final conclusion of the workshop series is being drawn. The whole procedure during the planning phase, the implementation and the evaluation is looked at and evaluated retrospectively.

In the planning phase three different topics for the workshops have been developed as already explained. During the advertisement of the workshop series, it has become apparent that the topic of balcony power plants is interesting for the most external participants, so the demand on this topic was much higher. Nevertheless, the people who attended the workshops were also very interested in the off-grid and self-assembly solar system workshops, but it was a challenge to reach a lot of people for these special topics in the first place.

Overall, promoting the workshop series proved to be difficult at first, because without a large distribution list it is difficult to reach interested people. The distribution via the e-mailing lists of the university and the city of Cologne helped a lot. Other possibilities, such as paid advertising on the internet, should be considered in the future. Despite reaching a large number of people, advertising via social media unfortunately did not result in many registrations for the workshops. This is probably due to the fact that the right local target group could not be addressed. Through the right strategy, the advertisement on social media could definitely improve.

The implementation worked very well from the beginning. And it proved true that a group size of 10 to 20 people is optimal, so that enough questions can be asked for the discussion and still everyone can be supervised in the practical part. The time allocation of approx. one hour each for the theoretical and practical part was also sufficient, especially that the practical part had an open end and thus some interesting discussions were held.

The survey is a good way to draw results from the workshop and get possible suggestions for improvement. Nevertheless, a concept should be devised to increase the number of participants for the second survey, as a low response rate makes it difficult to draw possible conclusions. Also, the used free of charge survey tool might not be optimal for a scientific evaluation.

Overall, the workshop series was successful and enjoyed by both the speakers and the participants. A continuation of the workshop series is definitely recommended as interest in solar system for the use in private households is growing steadily.

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