A Game-Like Interactive Questionnaire for PV Application Research by Participatory Design

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Abstract. Questionnaire is a necessary method for investigation and research, but it often scares participants because of the impression of being long and boring. We developed a game-like questionnaire as an effective method to collect information and ideas from participants. In this paper, we describe the use of this tool to facilitate a photovoltaic (PV) application research, which is led by the University of Southern Denmark. The research is collaboration between local companies to popularize PV technology in both residential and the industrial markets. For such an innovative research, the interactive questionnaire developed by means of participatory design has helped us get a balanced perspective between user needs, market viability, and technical feasibility. Moreover, this tool guided our research focus on the artistic and usability aspects, and also raised design concepts and the concern of practice issues.

Keywords: Participatory design, Solar energy, Game-like questionnaire

1 Introduction

The growing trend of solar energy attracts more companies and institutions to work together to catch the opportunities in the area of future energy supply. As to a general impression, solar energy has low efficiency, unstable current flow, and high price. But today, the fact is changing faster and faster. A well-designed system and a well-selected place will generate considerable power at a competitive price. A Photovoltaic (PV) system consists of several high technological components. They should be compatible with each other, adaptive to the installation environment, and accordant to the user's need. Participatory design balances the perspectives between different fields and involves more people to think together to contribute design concepts [1]. We believe that it was necessary to build an interactive tool that can facilitate usability research and idea generation effectively. The development of this tool and subsequent usability research is part of the Sunrise-PV project.

This Paper mainly introduces our development process of the interactive research tool, and the result of the tool. It also includes part of the research result from this

tool. This development process is dynamic, that means the tool is used in from the beginning of the research and was revised in each step.

The Sunrise-PV project is an industry-oriented project led by the Mads Clausen Institute (MCI) at the University of Southern Denmark and with the participation of Danfoss Solar Inverters A/S (DSI), Sydenergi (SE), Linak A/S, Esbensen Rådg. Ing. A/S and ProjectZero A/S. The project is partly funded of the Danish "Region Syddanmarks Vækstforum" and the European Regional Development Fund. Two large solar plants are party financed by the project, a 28 kW PV-plant on EUCSyd and a coming 80 kW plant at Produktionshøjskolen, both in Sønderborg, Denmark

The goal of the project is to develop new concepts, technologies and products in the field of PV systems with the main purpose of generating new jobs and companies in Southern Denmark. The activities in the project include both technical (inverter technology, tracking and control systems) as well as user oriented and design oriented activities with the focus on Building integrated Photo-Voltaic (BIPV).

To make full use of the particular advantage of solar energy, usability research is one of the essential sections in the Sunrise-PV project. We utilized the participatory design to promote the stakeholder and companies' cooperation, and to carry out a reasonable design solution, which fits the condition in Southern Denmark.

We defined one of our research questions as "How to improve the value and competences of solar energy for residential areas compared to other mainstream renewable power sources".

2 The research

2.1 Research issues

Basically, we can see that PV is having advantages regarding environmental acceptance, as they do not like wind energy produce shadow effects from wings or acoustic noise. They also have only little visual impact on the landscape. The demand of the place that fulfills the requirement of setting up a solar system is low. However these advantages are not common sense of the public. The focus of utilizing energy could be very practical like price, payback time, and how difficult to get. To take PV energy into mass markets, we need to facilitate from two directions. One is to hear the perspectives from end users, technicians, government, and scientists. The other is to popularize the knowledge and current state of PV to the public.

The initial focus was put on residential buildings. To get practical experience from private house owner and professional knowledge from stakeholders, questionnaire is necessary for the investigation. However the questionnaire has the impression of being long and boring, which scares participants and lowers the quality of the investigation. Therefore, we decided to develop a web-based program that is a game-like questionnaire to make participants enjoy the process of participating. The main questions for developing this program are how to choose the content and how to design the game-like interactions. The participatory design process provided rich materials to solve these two issues.

2.2 Approach for participatory design

The content of the interactive questionnaire is selected from the range of previous solar energy research that was focused on five basic fields. Much discussion has been on the balance between some of the following aspects: Economy, Ecology, Art, Technology, and Usability [1][4]. As the issues we mentioned above, solar energy has no significant predominance over wind power or waterpower in terms of economy, ecology, and technology. Governments or large companies always plan the construction of wind or waterpower. However, to mass market, the owner of a private house is more concerned about art and usability. Thus, we put the focus of the questionnaire on Art and Usability.

We followed serveral participatory design principal to design our research. As participatory design is a method through the whole process of an interaction design project, and the design is conducted in the working environment, users are part of design team [7]. Developing an interactive tool is also a user centered information design. Thus, besides user, we also involved other stakeholders including marketing specialist, usability manager, and technician in to the research [8]. The process of a participatory design can be inducted into 3 iterative steps: get public information, facilitate design workshop, and collect feedback [9]. To be specific in our research, we design following steps: investigation of the current situation and existing applications in Southern Denmark, the communication with local companies and private homeowners in four important towns from Southern Denmark, and the implementation of the web based questionnaire (game-like) for involving more participants. The outcome of each step contributed to the next step as design material. Finally, we presented one of the possible design concepts, as an example to inspire designers for later development. Through the process, we not only collected the knowledge and ideas for solar system, but also got the suggestions and ideas for designing the game-like questionnaire.

Besides the focused fields and the process, the groups of participants are also defined in our research. Essentially, there are four participants groups: end users, demonstration sites owners, technical support, and research specialists. Each group plays different roles in each step of the process. E.g. the end user group played a complimentary role during the investigation step, since the first step is put focus on studying and collecting fundamental knowledge about existing state of affairs of PV solar energy. But in the second step, the user is the core group to which we introduce the knowledge and send questionnaires to. User feedback is the significant part of the research output. The users list the priority between each research field, and speak out their own experience and story about solar and green energy.

In addition, the cooperation of the companies, in this study synthesized architectural design, user research, marketing investigation, and solar system testing. We have paid particular attention to technology development, sun tracking, green energy innovation, and building installation experience in our project. These professional participants contribute to knowledge in the five fields respectively. They provide and exchange rich information between each other and to the end users through the seminars. The information is also transferred to other participants by our web-based questionnaire.

3 Investigation, Communication, Implementation

Study and investigation is a usual start for an innovative project [6][9]. After the investigation of synthesizing data from Internet search, public research reports, and library resource, we build communication with experienced owners of solar plants. Danish town Skive have been placed several solar energy facilities on public buildings. All schools and many institutions currently receive energy from solar panels in Skive. According to the calculations, one of the projects, which were set up in 2009, is expected to have a payback time of approximately 12 year [2]. The experiences from Skive showed us an exemplification of utilizing solar system in the Danish geographical condition that it has relatively less sunshine in the world, and that daylight is much longer in summer. The top three remarkable aspects of Skive government are capacity, cost, and size, for which we particularly created one section in the interactive questionnaire to see other participants' perspective.

Our investigation also involved several conferences and seminars in Denmark to gain information about energy technology, economy, and policy. The Danish government has no special feed-in tariff for solar energy, but they allow a household photovoltaic installation, which is smaller than or equal to 6 kilowatts (kW), to use net metering. Net metering means that the contribution of a PV system will get the house energy meter to "turn backward" using the power grid as storage place for energy and can result in a zero-consumption of electricity on an annual basis [10]. The configuration of a 6.4 kWp PV system needs 41 square meters, and costs in the order of 126,000 DKK in 2012[3].

Building Integration Photovoltaic (BIPV) is one of the most relevant fields of our research. BIPV is a solution that not only generates energy but also protects facades and provides nice design [1]. Some solution adopts flexible solar cell to fill roof for temporary use or fill a surface in special shape. Architects have right to choose these solutions and materials, thus, we contacted architects who are members of our network in Denmark. They indicated their interest in environment matching, orientation of light, and energy generation by priority. They also prefered to use pictures to show their ideas, which inspired us to insert BIPV pictures in our program. See **Fig. 1.**

Fig. 1. BIPV example in the game-like questionnaire

We designed several posters which published on our website (http://bit.ly/U1Q2YQ) to share the aforementioned investigation to other participants, especially to the end user group, who had outdated information of solar system. To get an overview of

users' feedback in Southern Denmark, we held four seminars and took turns in Odense, Sønderborg, Esbjerg, and Kolding. SydEnegi, Danfoss Solar Invertor (DSI), ProjectZero, and Mads Clausen Institute gave a presentation to household owners in their professional perspective, respectively. During these seminars, we took chance to interview participants about their perspective of solar system, invited them visit our website and try the interactive game (questionnaire), and leave emails to keep future tracking survey. We use the words "game" instead of "questionnaire" to attract people come and participate the research actively.

Many of participants considered to purchase a solar system because of the policy that equal and less than 6kW solar system for a household could get net metering. They pay close attention to the details about price and payback time. Our seminars gave the house owners a wider view for their choice. They started not only to think about total budget and payback time, but also to consider where to install the PV system and how the building looks after installation. Some of the people came and discussed their special needs with us. Some for example had to change the roof in a few years, so it could be a good idea for them to consider installing a solar system as well. It could thus reduce the overall combined cost for building material and installation labor work. A similar story can also be said about windows. Some wants to change old windows, and it might become a good idea to choose a PV window to have both functions of energy generation and shading. But feasible solutions for that are just now entering the market.

Based on the investigation in market and communication with end user group, we mapped the interest and focus of core developers, external cooperators, and end users in terms of what advantage PV can bring to our life, how to choose PV types, and how to use PV to help architectural design. The map shows the priority of the interest by the size of text as Fig 2. Consequently, these keywords showed us the most important concerns are payback time, why purchase a solar system (purpose), and appearance. We designed another section in the program that allowed participants to choose their preference in these three aspects.

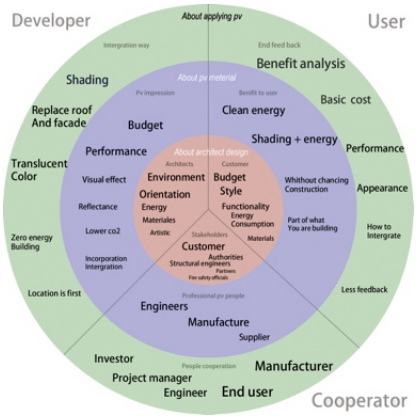

Fig. 2. Keywords of participants' interest

The program combined information introduction and collection, and gave several different approaches to interact with participants. We called it as game-like, because the whole process includes a variety sections and tasks. As questionnaires give a general impression as being boring, time consuming, and long, to design the questionnaire like a game could attract participants and keep them interested in accepting and giving information. It includes choice question, sorting order question, and open discussion task. The test of the online program can be found on http://bitly.com/S38Jvq See Fig 3. The input from participants is stored in a database. So far, we collected more than 40 answers that include all different kinds of participants and show a balanced interest of design concept. The top choice of the scale of a solar system is in 40-80 square meters in size, price is between 70,000 and 120,000 DKK, and expected payback time is less than 10 years. 70% participants pay attention to a nice look from outside, and most of the people looked forward to a feature of knowing operational details of in the solar system.

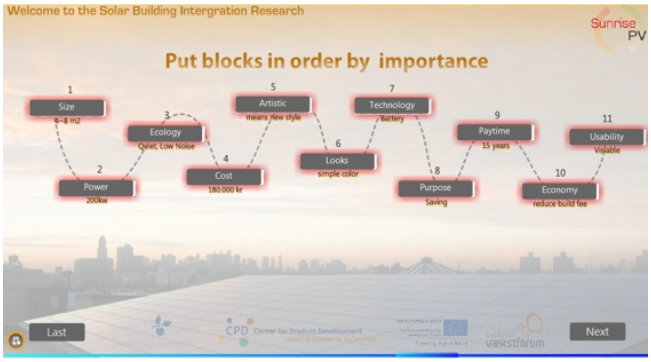

Fig. 3. A game-like questionnaire

A web based game-like questionnaire is aiming to provide an enjoyable and relaxing experience during participatory design. It clears up and re-organizes the mass of information from abundant research to help participants understand professional information easier, who are not only provide constructive suggestions, but the practical issues also rise up. This balance between negative and positive input puts the research result in a safe range and leads to later development.

4 Design and practical issue

Based on the overall research process, and the outcome collected from the program, we carried out several design concepts. A multifunction window that integrated PV system is one of the examples. The PV window could generate energy and provide shading at the same time. Moreover, a sun tracker system could help to adjust the angle of PV panels to improve its efficiency. A temperature sensor and a CO2 sensor can also be used for detecting indoor air quality, which allows the window automatically to open to get fresh air in. The energy from the solar system can support the

mechanical movement of the window and connect to the main power supply in house. See **Fig. 4.** It is an ideal concept following participants' imagination. Meanwhile it is also for developers to criticize on to get more inspirations.

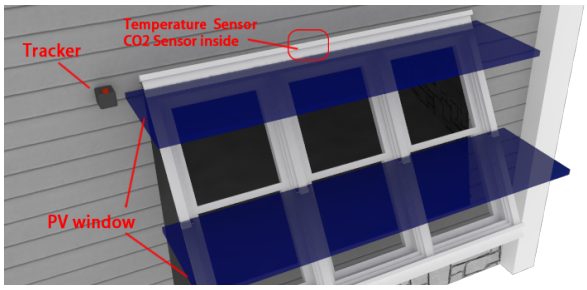

Fig. 4. Example of design concept

5 The effect on shading on solar panel

The program also gathered the concerns from professional technicians who paid attention on practical issues. One of the most-discussed issues is that shading has a more profound effect on the power generation of solar panels than one should intuitively expect. Having guided by the comments collected from the program, we did more research in this issue and found that it is due to the internal construction of solar panel with multiple individual solar cells interconnected. The participants who have technical background describe the detail to us: A single solar cell will generate a voltage of around 0.6 volt, which is too low for direct use. Solar cells are therefore in general connected in series inside a solar panel, so that a solar panel consisting of 72 solar cells will generate a voltage level of around 43 volt. If all solar cells have the same illumination, they will generate the same current, meaning that the same current will flow thru all the cells. But if some of them are shaded, they will generate less current and at the same time block for the higher current from the other cells, meaning that the resulting current from the panel is limited to the current from the cell with the lowest illumination. This effect means that even a small shadow can generate a large decline in power output, so it is important to understand that the loss in power is not proportional to the shaded area but can be much more severe. The comments from the program did not show up solution to this issue, but the expertise suggested us put the enviroment of construction in to consideration during the reasearch .

Conclusion

A web based game-like questionnaire can provide an enjoyable and relaxing experience during participatory design. It clears up and reorganizes the mass of information from abundant research and makes participants feel easy to understand the information, thereby bringing about more brisk ideas. The participants not only provide

constructive suggestions, the practical issues also rise up. This balance between negative and positive input puts the research result in a safe range and gives us a better connection with later development. At last, at the same time, the participatory design can contribute to both of the development of this game-like program and to the research project directly.

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