Engaging Electricity Users in Italy, Denmark, Spain, and France in Demand-Side Management Solutions

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Abstract. This paper presents the process of uncovering the motivations and barriers for adopting innovative solutions to increase the flexibility of electricity demand among individual consumers. Currently, efforts are being made to decarbonize electricity production with distributed solar and wind renewable energy installations. Such a shift in energy production also requires significant changes on the consumption side, in particular making demand more flexible to match the current situation in the power grid. The challenge in designing demand-side solutions is to accurately identify the needs of individual users so that they are motivated to take advantage of new solutions. Using data from a quantitative survey of electricity consumers in four countries (Italy, Denmark, Spain, France) on energy literacy, values and attitudes towards energy saving and technology, a cluster analysis was carried out which identified five types of electricity users. The segments defined in this way were the basis for conducting qualitative creative workshops with experts dealing with modern solutions in the field of energy and with individual electricity users. Subsequently, this information was supplemented with theoretical knowledge from the field of economic psychology regarding decision making, cognitive processes and motivation. This method allowed, already at the early stage of innovation design, to identify motivations and barriers specific to individual groups of users. The designers of innovative solutions received valuable clues as to how new technologies should be designed in order to ensure that they are well aligned with the habits, needs and rhythm of daily routines of the users.

Keywords: Energy usage flexibility · Demand response · Energy saving · User engagement · Motivations · Smart grid solutions

1 Introduction and Related Works

In this article we describe a method for incorporating a social and user perspective into the process of developing a technological innovation for opening the flexibility of electricity demand among individual energy users, with some preliminary results. The aim of the paper is to communicate this experience to other researchers and developers working on technological innovations, both in the energy sector and elsewhere. We believe that by

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using this approach, technological solutions can be better aligned with user needs and preferences, and therefore have a better chance of successful implementation.

In the face of the climate crisis, international efforts are being made to decarbonise the energy sector by developing low-carbon energy sources [1]. Such a change will require a fundamental re-engineering of both the way energy is produced and the way it is used. While changing the way energy is produced is a technological task that requires a plan and a budget, changing the way energy is used implies a social change that requires consumers to understand and accept new ways of using energy.

At present, the decarbonisation of energy in the EU mainly concerns electricity, which in future is to be generated mostly with low emissions technology - alongside nuclear and biomass, wind and solar energy are expected to become important sources. The main problem with wind and solar energy production is its variability and the difficulty in forecasting the available amount. Also, with the development of photovoltaic energy, an increasingly important problem for the power grid is the misalignment of peak energy production (middle of the day) and peak energy consumption (evening hours). This reduces the efficiency of energy production and increases costs. As there is no technology allowing the cost-effective storage of a significant share of the energy consumed, the increasing share of solar and wind power requires individual consumers to adapt their daily rhythm of electricity use to the current availability in the grid [2], so that more renewable energy is used, reducing both costs and greenhouse gas emissions.

Energy consumption patterns of individual consumers affect both the general level of energy consumption and the flexibility of energy demand. Shifting a portion of energy use from peak hours to other times reduces peak load on the grid, allowing energy needs to be met by infrastructure with lower energy production potential. However, the concept of flexible electricity demand is an entirely new concept. Most users are not aware that it is important not only to reduce the amount of energy used but also to adjust consumption patterns to energy availability.

This can be achieved, for example, by avoiding the use of energy-intensive equipment, such as air conditioners, water heaters, or washing machines during peak load hours, or by limiting the intensity of heating or cooling during those periods [3]. Such actions reduce stress on the electricity grid, decrease CO_2 emissions and reduce cost. This is why it is so important not only to develop new technologies that enable a decarbonisation of electricity generation, but also to involve electricity users, as they play a key role in this process.

Designers of systems for smart energy management are confronted with a serious challenge. When optimising the operation of the system, they have to take into account a number of factors, including the needs of energy producers, users, as well as technological possibilities. There are a number of studies highlighting the complexity of this problem and assessing what factors increase the likelihood of success for energy business innovations. Researchers look at this topic from the perspective of business models [4, 5]; assessing how people can be motivated to behave in an environmentally responsible and climate-friendly manner [6] or evaluating price incentives for programmes promoting time shifting of energy consumption [7]. David Halpern highlights the importance of simple actions based on knowledge from behavioural economics to change behaviour and identifies four general characteristics of effective action, summarised under the acronym

EAST (Easy, Attract, Social, Timely) [8]. Researchers also describe the success factors for adapting new technologies for home energy management. Guerassimoff and Thomas explore how a web interface and loyalty programme can keep users engaged in energy management actions [9]. Wilson, Hargreaves and Hauxwell-Baldwin evaluated how perceived risks and benefits affect perception of smart home technologies [10]. Kowalski and Matusiak evaluated how the use of IoT solutions redefines the concept of electricity [11]. This article describes a case study on how best practice and guidance from previous work has been applied to match a user's needs with technological solutions right from the design stage.

2 Methods

In our approach, we decided to use a multi-stage method. This approach was intended to support the design of the user interface of a system for managing household electricity consumption. The following sources were used to gather multidimensional perspective about users and to prepare guidelines on how to modify patterns of their energy consumption behavior:

1. Scientific knowledge on decision making, cognitive processes and motivation. The work included concepts such as Priming, Framing, Social Scripts, Exposure Effect, Heuristics of ease, Intrinsic motivation, Values, Self Identification and others.
2. A quantitative survey of electricity consumers, carried out in June 2020, in the four European countries: France, Spain, Italy and Denmark (N = 3200, random-quota sample, matched to demographic structure in each country, Computer Assisted Web Interview). The aim of the survey was to find out about electricity users in terms of their knowledge, attitudes towards the environment and technology, and their approach to saving energy and its efficient use. The interview lasted on average 20 min.
3. Cluster analysis on data from the quantitative survey, identifying types of electricity users (segmentation, hierarchical clustering method).
4. Qualitative profiles of the typical user (Personas). With this method, the quantitatively defined segments served as a basis for qualitative analysis and preparation of descriptive fictional portraits of characters who are typical representatives of each user segment.
5. Co-design workshops, carried out with both individual electricity users (2 workshops) and experts from the energy sector (1 workshop). Workshops were conducted online, via the freely available Jamboard platform and lasted about 3 h each. The aim of the workshops was to identify the main motivations and barriers to Demand Side Management (DSM) and to develop ways to motivate users to use the two solutions (Fig. 1):

   a. Smart energy management of home appliances
   b. Vehicle-to-Grid charging station at place of work.

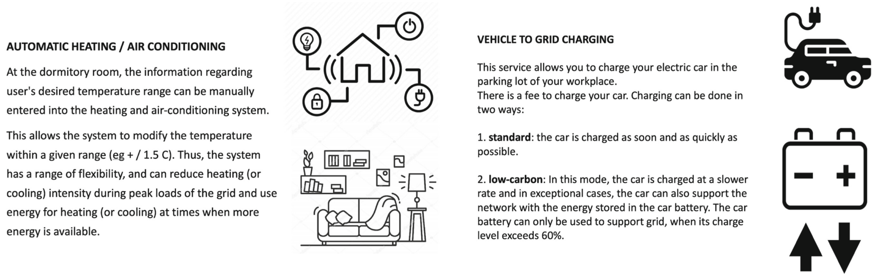

Fig. 1. Concepts evaluated during co-creation workshops.

3 Results

The quantitative survey carried out in the first phase provided knowledge about the structure of electricity users, their level of energy literacy, owned electrical appliances and attitudes. It also evaluated three preliminary concepts of solutions to increase flexibility of electricity demand. This stage showed that most users are open to new solutions concerning energy use and have a positive attitude towards technology. The main motivators for using new solutions were the financial benefits and the reduction of negative environmental impacts.

To better understand the structure of users and to establish a communication strategy tailored to the needs of specific user types, a segmentation analysis (hierarchical clustering method) was carried out on the quantitative survey data, which distinguished 5 user segments, named: Dynamic Traditionalists, Sceptics, Affluent, Supporters, Open and Modest. Figure 2 shows the results in a simplified, synthetic form, the number of dots indicates the relative intensity within the variance between the identified segments.

	Open and Modest 53%	Supporters 20%	Sceptics 13%	Dynamic Traditionalists 12%	Affluent 3%
Energy Saving	●●●	●●●●	●	●●●	●●●●●
Energy Literacy	●●●	●●●●	●	●●	●●●●●
Energy Consumption	●●	●●●	●●	●●●●	●●●●●
Main motivation to Save Energy	financial, environmental	financial, environmental	financial	financial, new technology, environmental	financial, environmental, new technology
Energy Equipement	●●	●●●	●	●●●●	●●●●●
Electric / Hybrid cars	●	●●	●	●●●	●●●●●
Age (more dots = older)	●●●●●	●●●	●●●●	●●	●●
Social activity level	●●●	●●●●	●●	●●●●	●●●●●
Household size (no. of people)	●●	●●●●	●	●●●●	●●●
Income	●●	●●●	●●●	●●●●	●●●●●
General Values	Sensitive, cooperative, fulfilled	Sensitive, energetic, positive, fulfilled	Traditional, sceptical, reserved	Traditional, reserved, active, dynamic	Active, ambitious, open-minded like to stand out
Environmental Values	●●●●	●●●●	●●	●●	●●●
Attitude to technology	●●●	●●●●	●●	●●●●	●●●●●
Education	●●●	●●●●	●●	●●●●	●●●●●
City size	●●	●●●	●●	●●●●	●●●●●

Fig. 2. Summary results of the segmentation analysis performed on the data collected in the quantitative survey of electricity users (N = 3200), showing the dimensions that differentiate the different user groups.

This analysis has helped to identify priorities in communication with users, tailored to their characteristics. It also showed that those individuals who are most sceptical of change and reluctant to save energy also have the lowest relative income and, regardless of their views, already use significantly less energy than users from the other segments. The analysis showed that users in the other segments are generally open to changing the way they use energy and have a positive attitude towards technology, which indicates a relatively high potential for acceptance of new solutions.

Once the key user groups were identified, qualitative profiles of the typical user (personas) were developed so that the characteristics of a typical user representing a segment could be portrayed in an accessible way. Figure 3 shows an example of such a description, for a user from the Open and Modest segment.

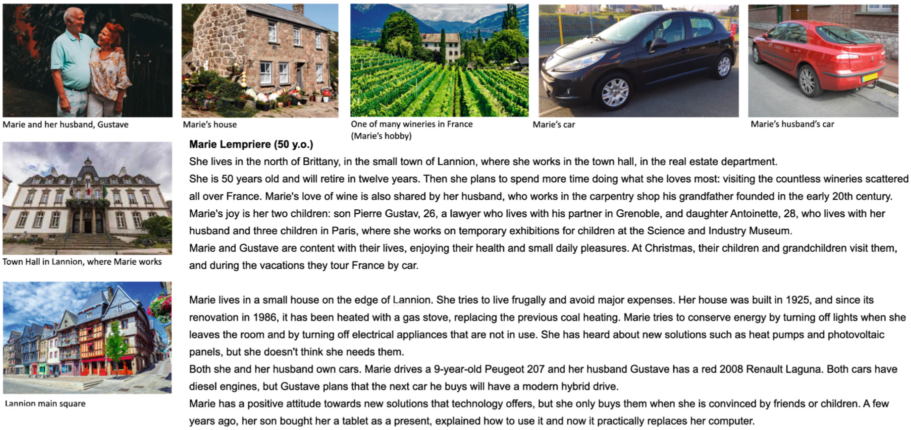

Fig. 3. Qualitative description (persona) of a fictional energy user, representing the Open and Modest segment.

The personas prepared in this way were used in co-design workshops with energy experts and individual users. The results of the workshop indicated a number of non-obvious, previously unnoticed needs and motivations. For example, in the case of Open and Modest users, the relatively oldest user group, it emerged that an important motivation for using smart energy management devices may be a dimension not directly related to energy consumption, namely - safety. This dimension manifests itself in the need for physical safety - e.g. automatically controlled electrical appliances can reduce the risk of fire caused by burning electrical appliances that have not been switched off by mistake. An energy management system can prevent such risks with built-in functions that warn the user about devices that have not been switched off. The safety dimension can also be understood as support in the use of electrical appliances through automation of controls. It is difficult for an older person to manually set the operating parameters of a number of electrical appliances and here the DSM system can help by automating their management. Finally, there is also a financial aspect to the safety dimension, because by reducing the costs associated with energy use, financial security is increased, which is particularly important for senior users who expect their income to decline with age.

The workshop also brought new insights for users from other segments regarding their motivation to use smart electricity management systems, that due to space constraints are not presented here.

4 Discussion

The above results were complemented with scientific knowledge on decision making, cognitive processes and motivation. On this basis, guidelines have been developed on how to use knowledge from both the scientific research and from the users to prepare a system that involves users to make changes in the way they use electricity, in order to reduce the load on the electricity grid and thus reduce the costs of energy production and associated greenhouse gas emissions. Getting users to change their behaviour is a difficult task, as it requires the modification of established beliefs and habits. It also requires additional effort. Therefore, actions encouraging people to change their current pattern of energy use should be multi-dimensional, so as to show the importance of the values on which the new behaviour is based, strengthen the motivation to maintain the desired behaviour, provide knowledge justifying the change of behaviour and activate actions on a broader than individual level. A good example of an environment where such programmes can be pilot tested is a university campus. A university can promote values and behaviours through its activities, organisation and communication to students. The effectiveness of such activities is enhanced by the fact that the university creates a cohesive and well-defined community that is open to change and the introduction of new knowledge-based solutions.

5 Conclusions

With the method presented, it was possible, already at the early stage of designing innovations, to identify motivations and barriers specific to particular groups of users. The developers of innovative solutions received a detailed report, with valuable clues on how to integrate new technologies with the habits, needs and rhythm of daily activities of users.

The process described proved to be simple to implement and cost-effective. Although it required additional work for the researchers - analysis of quantitative data to prepare consumer segments and personas, or the work needed to organise and conduct workshops, however, this did not involve a significant increase in total costs for the project. Work on the social aspects of innovations for energy management was carried out in parallel with the development of the technology and the results were discussed with engineers and technical experts on an ongoing basis. Although difficult to quantify at this stage, it seems reasonable to argue that a better understanding of the social aspects of the application of new technologies saves significant resources and time at the design stage and increases the chances of successful implementation. The approach presented can also inspire designers of other innovations. When designing new solutions, getting to know users well and matching their needs and technical capabilities is essential for success. We believe that this practical example of how the user perspective can be incorporated into the process of designing technological solutions can be useful for other design teams looking for technological solutions in various fields.

The presented approach also has some limitations. Only the first stages of the innovation co-creation process have been presented here, consisting of collecting information about users and evaluating concepts. Currently, prototypes of solutions for managing household electricity consumption are being designed, taking into account the knowledge gathered in the process presented here. The evaluation of these prototypes, and then of the finished solutions, will be a true test of the validity of the approach presented.

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