Energy Efficiency: Do You Know Your Prospective User?

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Abstract: Smart homes are seen as an enabling technology and integrated part of future energy efficient system. However, actual level of uptake of Smart home energy solutions is still low. New energy solutions must be shown to be attractive and valuable before they will be accepted. To this end, the values and expectations of prospective user must be understood better. Inspired by Design Science research, this paper presents a novel method, found in synergy of scenario-based research, content analysing methods and user experience mapping, which helps to assess if the vision for Smart home energy technology is widely coherent between prospective users and industry.

1 INTRODUCTION

There have been significant technology advancements in the recent years to enable new disruptive solutions for the energy system, e.g. global digital mapping/streetscape, digital analytics, artificial intelligence and machine learning, etc. Further to this, smart metering has recently progressed through regulation, whilst storage, grid investments and electric vehicles are generally following economic incentives for profitability. In parallel, the Internet of Things, cloud technology and blockchain are fast becoming a common reality. However, even with these technological advancements, many industries are conservative and risk-adverse because these technology advancements are not adopted quick enough, preventing advancement and acceleration. New solutions must be shown to be attractive and valuable before radical system changes and quantum-improvements will be accepted.

Smart homes are seen as an enabling technology and integrated part of future energy efficient system, helping to optimise an overall demand response towards flexibility in distributed generation, storage and consumption of energy resources. Smart home technologies are increasingly on sale across the Europe, examples in Finland include smart home platforms, solar panels with various installation options included, intelligent automatic solutions to control heating and water systems as well as appliances and lighting, however, actual level of uptake of smart home solutions is still low. According to various market researches, the most significant barriers to adoption include a lack of awareness about available technology and its benefits, and also trust- and the interoperability concern (Harms, 2015). However, advertising and communicating benefits alone may be insufficient to attract prospective users of smart home energy technologies. Market players such as energy providers, home platforms- and individual solutions providers and consumers need to collaborate to create awareness and in particular common understanding about expectations towards the smart home energy systems, their features and the benefits of these systems. When solution providers and retailers are marvelling at the passivity of prospective users, latter are waiting for products that match their values and expectations.

The new smart energy economy, thanks to digitalization and novel technologies, causes utilities and market participants to engage in a variety of new relationships. These new relationships, ecosystems and changing business models will be among the important outcomes as the smart energy ecosystem evolves. Such new business environment necessitates the availability of data models and tools in place to aid the capture of those opportunities as they arise.

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These tools and data models needs to encompass various viewpoints and in particular the quality and consistency of the user experience and consumer motives, which need to be understood well.

Inspired by *Design Science research*, the novel method, found in synergy of scenario-based research, content analysing methods and user experience mapping, is proposed to understand better the consistency between prospective users' perceptions, values and motives and respective industry view on the smart home energy technology represented by their marketing material. The findings presented by this research aim at emphasising the importance of user experience research to be taken not only into the design of respective technology but also into its appropriate service proposition and support.

2 PROPOSED APPROACH

This research utilises the *Design Science research paradigm* in which questions relevant to a particular problem in an application domain are answered via experimenting and the creation of innovative artefacts, thereby contributing with new knowledge to the body of scientific evidence (Hevner et al., 2004; Hevner, 2007; Peffers et al., 2007). Sometimes design science research is also about potentiality i.e. the identification of new opportunities to improve practice before any problem is recognized (Iivari, 2007). Artefacts may be models, methods, constructs and instantiations. In our case, the business domain is a Smart home and energy-efficient systems and the created artefact is a proposed research approach, which is grounded on several scientifically recognised methods namely content analysis, scenario-based research and experience mapping, which are described in the following.

2.1 Web Content Analysis

The web content provides a comprehensive picture of how respective industry is representing the benefits, functions and use of products and services they offer.

Content analysis is a widely used method for studying documents and other communication media such as text in various formats, picture, audio and video. The qualitative and quantitative statistical methods can be used to analyse the meaning of the content by systematically labelling of the content with specific descriptors or "keyword concepts" (Krippendorff, 2004). Content analysis is used in many fields ranging from market and media studies to social and political science and sentiment analysis. The examples of applications in the energy domain include content analyses of online marketing by green electricity- and smart home technology providers (Herbes and Ramme, 2014, Wilson et al., 2017).

Accordingly, marketing material and products descriptions from companies active in smart home and energy market in Finland were qualitatively studied with a support of the content analysis process presented in (Bengtsson, 2016). Materials have included companies' web pages describing their products by text and pictures and videos accompanied by spoken or by written text. The 15 companies with profiles of energy providers, solution providers and retailers have been sampled. Their marketing material was targeted mostly at the prospective users i.e. householders. Sampled materials describe the main benefit of Smart home energy solutions as helping householders to monitor and control their energy use. Products are also commonly marketed as a means of improving household comfort (e.g., keeping individually adjustable environment conditions), or as a means of enhancing self-sufficiency (e.g., using own solar generated electricity in case of electricity failure). This provides benefits to users through money savings, convenience, efficiency as well as general enjoyment by doing things in "your own way". The solutions are also described as an easy to install and to use, "make sense choice", though the availability of professional help in installation of products is emphasised.

As a results of content analysis a major set of concepts associated with a question of research (perceptions, values and motives), which describes the view of industry on Smart home energy products has been established as represented below:

Increasing comfort	*Easy to use, easy to install, effortless*
Money saving	
Trustable, Safe	*Useful, sensible, making sense*
Exciting, Inspiring, Do It Yourself	*Increasing self-sufficiency*

2.2 Scenarios

In a next step, in order to obtain a respective view, experiences and expectations of prospective users, the scenarios in form of storylines were defined. The storylines describing the functions of products were based on the existing products' description and marketing material used in the content analysis.

The educational, communication and exploratory functions of scenarios have gained an importance in recent years. Scenarios are consistent and coherent descriptions of alternative real or hypothetical features that reflect different perspectives on past, present and future development which can serve for action (Van Notten, 2003). It is recognised that scenarios can be used also as a scholarly research methodology to produce interesting research, for generating new ideas and arguments and broadening the range of causal relationships that we study (Ramirez et al., 2015).

Consequently, the created storylines have been used for the evaluation purpose but also as an aid to identify new research needs and generate new knowledge towards stimulating new empirical or theoretical work, action research and possibly even to creating an 'aha' moment. The scenarios contain the descriptions of three products currently widely offered in Finnish market, namely "Smart home automation", "Solar panels for rent" and "Solar system to invest". Further two more future "products" in form of life-style descriptions have been defined to mirror the existing developments led by smart energy districts research (Monti et al., 2017). A Smart Energy District is a new model for energy generation and delivery particularly in a campus- like living style environment. The future developments of such aspects as energy prices, various alternative energy sources availability, self-sufficiency in energy, global climate agreements and socio- technical trends will influence people' personal values and motives for using certain future technology. Consequently, these will influence styles and ways of living in such districts and communities. The created scenarios containing the descriptions of respective products are presented in the Appendix.

Next, the developed scenarios were evaluated with a prospective users. To collect a quantitative data set, the survey instrument was structured in three parts. Part one contained questions to measure prospective users' perceptions of Smart home energy products offered in the market and a future trends outlined earlier. The question regarding each product under evaluation is asked in a form "What kind of impression do you get from the product or service or trend described..?". In addition, part two of the survey contained an open-ended question asking respondents to provide a few words "that first come to mind when you think about 'Smart home energy technologies'?". Part three was designed to measure the perceived benefits and risks associated with respective products and trends. The survey was implemented online leveraging the Questback software, https://www.questback.com/.

In the final step, the experience mapping software tool was used for the survey data analysis. The experience mapping is based on the principal component analysis of experimental quantitative data and is discussed in the following.

2.3 Experience Map

The *experience mapping*, a central theme in this research approach, is a user-centric in the sense that it ultimately aims to analyse, describe and take into product design experiences evoked by different kinds of systems in terms of perceived attributes and mental impressions associated with them, arising from interaction (physical or virtual) with the system. The attributes are of different levels, as illustrated in Figure 1.

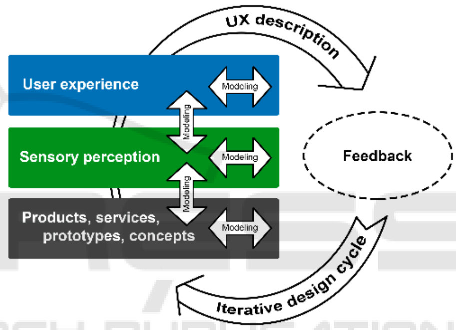

Figure 1: The experience mapping approach.

The *attributes at the bottom level* describe the physical properties, technical specifications, or creative design variables of the products and services being analysed and designed.

The mid-level attributes describe the sensory perceptions evoked by the products. Visual attributes are relevant, for example, when analysing the effect of paper properties on the perceptions and experiences evoked by printed products such as magazines. Such attributes are also important in analysis of effect of material on the perception of physical product. In this case it is essential to consider the multisensory nature of perception and include also haptic attributes such as roughness and slipperiness, loudness and softness or aggregated touch and feel attributes (Civille and Dus, 1990; Mensonen et al., 2010).

At the highest level the attributes describe the samples in terms of higher-level user experience dimensions. This research focuses on this type of perception. At this level products may be described in terms of cognitive appraisal dimensions such as perceived trustworthiness, interestingness, or usefulness; in terms of emotions and moods evoked by the interaction with the product, or more simply by the look and feel of the product; in terms of attributes related to aesthetic appreciation; or in terms of other kinds of mental impressions associated with the product, such as softness, luxury, efficiency, convenience, or affordability, for example. Attributes may also be related to such aspects of user experience as attractiveness, engagement, flow, or transportation (Steffen, 2007).

The concept of the experience mapping, similar to preference mapping methods commonly used in consumer research and sensory science (Carroll, 1972; Meullenet et al., 2008), was initially designed as a research tool for analysing those aspects of user experiences of digital and print media products and services that arise out of visual and multisensory perception (Laine, 2018). Here the experience mapping is extended to provide with data-driven insights to support identifying trends and understanding consumer groups and their motives for targeted service innovation in the Smart home and energy sector.

Once the relevant product-related attributes have been measured by means such as psychometric experiments or user questionnaires, the relationships between the different attributes as well as different products are analysed by means of multivariate statistical data analysis and then visualized in a diagram known as *an experience map*. More specifically, principal component analysis is applied to map the locations of the evaluated samples (products, services, concepts, or scenarios) from the high-dimensional space where each attribute corresponds to a single dimension to a lower-dimensional principal component space. Principal components are linear combinations of the attributes, such that the first principal component explains as much of the variance between the multivariate observations of the samples as possible, the second principal component then explains the maximum possible amount of the remaining variance in the data, and so on.

The questionnaires applying Osgood's (1952) *semantic differential scale* are often been applied in collecting such attribute assessment data. The semantic differential rating scale is typically presented as a line whose end points are anchored by attributes that can be considered to be opposites of one another, e.g. warm and cold, simple and complex, and interesting and boring. Many usability questionnaires employ such rating scales (e.g., Chin et al., 1988; Hassenzahl et al. 2003, Schrepp et al. 2006, Hassenzahl 2010).

Figure 2 shows a sketch illustrating the basic concept of the experience map. The horizontal and vertical directions in the map correspond to the first and second principal components, respectively.

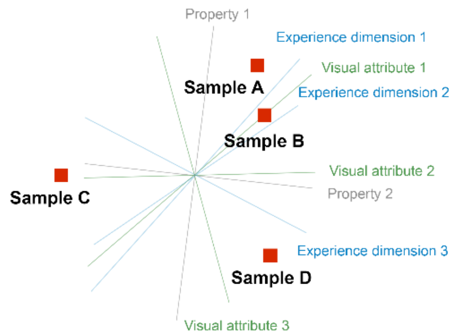

Figure 2: The experience map diagram.

The product locations are denoted by red squares (Sample A, B, etc.). The vectors of different lengths and orientations originating from the origin of the diagram correspond to different attributes (cold/warm, interesting/boring). Attributes of different levels are further distinguished by vectors of different colors. The basic principle of interpreting the map is that products located close to one another evoked experiences that were relatively similar to one another, while differing more from the experiences evoked by products located farther apart in the map. However, the numerical distances between the samples on the map do not generally correspond to perceived overall (dis)similarities between the samples, but are only approximations. Attributes whose vectors point in the direction of the given products were generally more strongly associated with those products than with other products. Further, attribute vectors pointing in the same direction indicate higher positive correlations between the corresponding attributes, while attributes whose vectors point in opposite directions were negatively correlated in the data. Roughly perpendicular vectors indicate low correlations between attributes or uncorrelated attributes.

3 VALIDATION

Alignment between prospective users' perceptions and industry marketing is an important indication of shared and consistent expectations for the Smart home energy market (Wilson et al., 2017).

As discussed earlier, the content analysis has provided a systematic picture in form of extracted concepts describing how industry is seeing and representing the benefits and functionality of Smart home energy products.

In order to obtain the correspondent view from prospective users, the methodology described in section 2.3 was followed. First, a set of experience dimensions were formed. The dimensions were based on the set of concepts resulted from the content analysis described in section 2.1 (increasing comfort, easy to use, safe/trustworthy, etc.). Next, the respective attributes in form of opposites in a scale of 1 to 7 were formed, such as, for example, increases comfort (1) – doesn't increase comfort (7), easy to use (1) – difficult to use (7), etc. In addition four more concepts were added, one to clarify a general awareness of respondents about products offered in the market and three others are to measure respondents' perceived interest in particular product or trend in general and an associated impression invoked by product such as if it is perceived trendy or old-fashioned, luxurious or ordinary. These additional attributes are not directly matched to the concepts representing industry' marketing material. They are, however, interesting for the future research, in particular in relation to the analysis of life styles and sociological aspects of technology use.

The quantitative assessment data were collected using online questionnaires as described in section 2.2. The sample comprised n=42 respondents with different professional background in the domains of engineering, sociology, medicine and economy. The age of respondents were in the range of 35-50 equally representing males and females. The results of the analysis of respective concepts using experience map tool are presented in Figure 3, where the samples have been mapped from the original high-dimensional attribute space to the plane of first two principal components, as explained in section 2. Here, the horizontal and vertical axes, not labelled in the diagram to avoid clutter, correspond to the 1st and 2nd principal components, respectively. The attribute vectors were similarly mapped to this principal component space based on their principal component coefficients, i.e., their contribution the 1st and 2nd principal components of the data set.

As an immediate observation, it can be seen that products 2 and 3 evoked impressions that were similar to one another, and in some ways opposite to the impressions evoked by product 1. Both solar panels-based products (2 and 3) were perceived as more useful and making sense as well as saving money than for example Smart home automation system (1). Accordingly, users' impressions or experiences for the solar based products are better aligned in these measures with industrial marketing. It is interesting also to find, that in spite of that solar technology is relatively new thing in Finland, respondents are better aware of these types of products compared to Smart home automation. On the other hand, Smart home automation system is perceived easier to use and more trustable compared to other products. Moreover, the respondents see all three products more difficult, old-fashioned and ordinary than interesting, exciting and trendy, in particular when compared to product/trend 5.

Furthermore, speaking about trends, "Age of high-tech" community life-style (4) appeared to invoke impressions that were rather similar to the products existing in the market. On the other hand, Do It Yourself & Smart scarcity way of living (5), which emphasises immaterial values, practical mind-set, do it yourself attitude and high environmental standards found more interest in respondents.

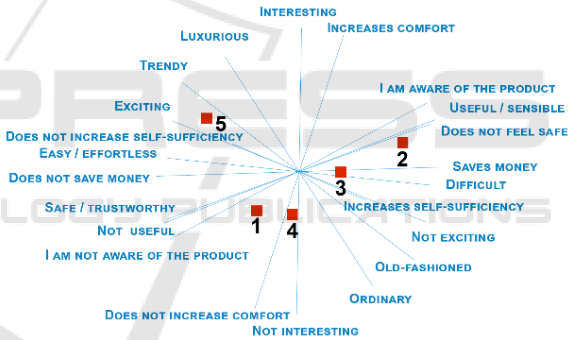

Figure 3: The experience of prospective users (1 – Smart home automation; 2 – Solar panels for rent; 3 – Solar system to invest; Styles: 4 – Age of high-tech; 5 – Do It Yourself & Smart scarcity).

The comparative analysis resulted from experience map has been complemented with analysis of how prospective users perceive *benefits and risks* of Smart home energy products.

As can be seen from Figure 4, respondents perceive potential benefits of Smart home energy technology to be rather general energy saving and ecological reason than other benefits emphasised by industry such as monitoring of energy use, increasing comfort, money saving and property value increase.

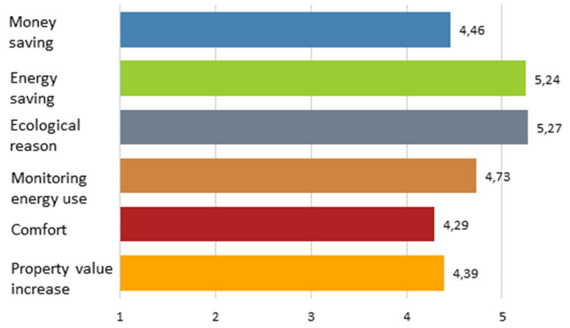

Figure 4: The experienced benefits of Smart home energy system.

Further, a majority of industrial marketing material puts emphasis on easiness of installation, availability of professional support and use of mobile internet applications. However, the results of quantitative analysis (see Figure 5) indicate that prospective users more strongly perceive potential risks in exactly those areas, - in the increasing dependency on mobile phone and internet as well as on a help of external experts including energy providers.

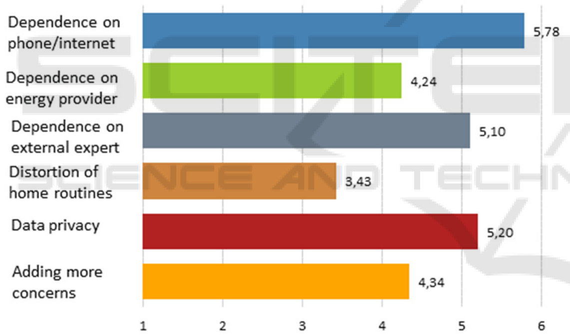

Figure 5: The experienced risks of Smart home energy system.

The initial analysis of feedback given by respondents upon an open-ended question asking to provide a few words about what first come to mind when you think about 'Smart home energy technologies' revealed, that 'Smart home' and 'Home Energy products and services' are seen as rather separate concepts invoking different rather disconnected impressions. This is something that needs to be followed further by product developers, retailers and energy policy makers.

4 CONCLUSIONS

To achieve the necessary energy transition in smart homes and cities, it is essential to increase energy systems interoperability and to push energy performance levels significantly beyond the levels of current building norms. However, these transformations cannot be made without the prospective user at the centre of the approach. In many instances, solutions are developed with a focus on the environmental and economic impact, however the social impact to/of the user is very often overlooked or not given the level of importance it requires. In order to identify the best solution, it is first necessary to understand consumer decisions and motives. It is thereby important to recognise that a decision to integrate new technologies is not a separate decision but connected to other decisions in the home and influenced by many factors. For the overall majority of the homeowners, energy efficiency or even cost reduction is not a main reason to integrate smart technologies, but other values can be the key objectives.

This research presented an approach which help to understand better if the vision for Smart home in energy domain is widely coherent between prospective users and industry. Shared visions and expectation for risks and benefits of Smart home energy solutions are important for reducing uncertainties with development and penetration of technological innovations. To validate a proposed approach, the quantitative analysis of a survey data on prospective users' perceived experiences of Smart home energy products and services and a web content analysis of respective marketing material offered by smart home and energy solution providers were performed. There are however limitations to the interpretation insights introduced by this validation due to the limited number of respondents participating in the initial validation survey (n= 42). Consequently, in the future we plan to evaluate the approach with larger group of participants.

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APPENDIX

The original scenarios evaluated with respondents were defined in Finnish language (along with a concepts and experience dimensions presented during validation). The scenarios below is a translated version created for a sake of clarity of discussions presented in this publication.

Product 1 – Smart home automation

Nowadays, Smart home technology, as well as measurable and controllable equipment can be installed in old and new apartment buildings. You can manage your home's functions with your computer or smartphone from anywhere, for example, to check if a home device is left un-switched when needed. In addition, the lights and home appliances can be switched off and on or the electric car can be pre-charged remotely. The service follows the evolution of the market price of electricity every hour, so in addition to monitoring, residents can transfer electricity use to less expensive hours. For example, if it is possible to wash the laundry in the middle of the day. After logging in to the online service of the Smart home application, you will see the current day's data on the consumption of electricity and hot and cold water. With knowledge, residents have the opportunity to better understand where to save. The system is estimated to allow an average of 15% lower electricity and water consumption per apartment. Other benefits of the system include the construction of additional functions and services over time. It could be useful, for example, in elderly care: if the coffee machine isn't turned on at the usual time, the caregiver can check to see if the resident has everything right. The remote control service requires measurement and control equipment for electrical equipment installed in the house. The cost of the *solution is between EUR 2 000 and EUR 3 000 per apartment.*

Product 2 - Solar panels for rent

An individual can now produce electricity without having to build a system of its own. You can rent your own nameplate from the solar power station. In practice, renting is done online by clicking on the solar panel map. The price is about 4-4.5 € / KK. Your panel produces electricity all year round, including on sunny winter days. You can keep track of the production of power plants on the web, even with a mobile phone or tablet. In addition, you can compare your solar panel production to your own electricity consumption. The electricity generated by your solar panel is credited to the electricity bill according to the stock price. Production varies by season. The average payback is about € 1 per month. On average, the output of a single solar panel is 230 kilowatt-hours per year, which is enough for running, for example, 230 washing machines or a 163-day television marathon.

Product 3 – Solar panel package to invest

In addition, residents have the option of acquiring a solar panel. Energy companies offer solar panels of various sizes that make it easy to produce solar power. Solar packages include a photovoltaic system and electric storage. When buying a package, the companies guarantee the right length and width of the panel for your roof. The package also includes an electric storage facility that will help the small producer gain more. For example, it can be used to store electricity and use it later in the evening when the sun is no longer shining. Through the electric storage, you can monitor the use and consumption of electricity. Electricity storage can save you at the time of trouble if you hit a power outage. Depending on the size of the house and the number of panels, the package price is on average 400 € per month.

Smart Energy Communities – year 2030

There is strong public demand to reduce greenhouse gas emissions and global warming. It is well noticed that renewable electricity generation maintains a steady pace of growth. When new districts are built, the builder designs energy production of a district tailored to this specific area and regulations. If the area is suitable for wind or solar energy, they are chosen. Wood and biogas if found is also an option in the area. This results in forming of smart energy communities around cities and in rural areas. Communities are well connected to each other and cooperate in various ways around energy and food production and consumption.

Product 4 - Age of high-tech

Local solutions using renewable energy sources are becoming widespread with local ownership and commercial services for maintenance and operation. Electricity consumers enthusiastically limit their energy use and generate their own energy. As the energy production became locally owned by the members of the community, a new sense of connectedness emerged. The culture of energy efficiency as a status values emerges from energy-smart technologies. This includes fuel-cell-powered sports cars, home automation and personal electronics along with certificates of the energy and resources used for their production. A whole new level of technology and product development is reached with this new willingness to pay. The culture of consumerism gives way to culture of valuing smart innovation and new cultures and communities. Novel technology made mobile electronics and gadgets energy independent by enabling them to harvest power from their surroundings. High-tech countries and companies thrive.

Product 5 – Do It Your Self & Smart Scarcity

Immaterial values have gain more emphasis in steering technological, economic and social developments. Communities are densely built with lots of shared public spaces. Lifestyles are localised. Travelling long distances is rare. Shared electricity cars is a way to go. Within communities, smart scarcity is the driving principle. Everything is recycled with almost zero-waste. Solar panels, windmills parks and other means of renewable energy harvesting provide communities with plenty of energy. Food is produced and consumed locally and according to seasons. The world is built bottom-up in a 'do it yourself' manner. Engineering skills and a practical mind-set are highly valued. 'Do it yourself' people are communal nomads who constantly develop new projects while helping others. Together, people innovate, get feedback and achieve increasingly high environmental standards in the spirit and the philosophy of continuous improvement.