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ENERGY EFFICIENCY ENABLED BY SYSTEMATIC INTEGRATION OF END CONSUMERS BY USING AN INNOVATIVE INTERFACE

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ABSTRACT

The present study draws attention to increasing energy efficiency in private households enabled by systematic integration of end consumers by using an innovative interface. The object of investigation is referred to technical and social requirements towards a consumer interface to present energy consumption. As the success of interfaces is a question of consumer-friendly design it was questioned what are the technical requirements, the consumers' expectations and to what extend do they meet. Therefore N=48 students took part in a user experience study. They were asked to complete an online questionnaire including different visualizations for energy consumption on a mobile interface. The results showed that different forms of visualizing energy consumption have different effects on the evaluation, user experience and in the end on the transparency of energy consumption. The present findings suggest that further investigation on specific design aspects of energy consumption is necessary.

1. INTRODUCTION

In times of increasing energy consumption on a global level connected to increasing prices for energy and a foreseeable exhaustion of fossil energy sources, it is a central task of science, politics, economy and society to assure a stable energy supply and a sustainable environment protection at the same time. The essential technical and political challenge is to reduce energy consumption, increase energy efficiency and extend the usage of renewable energies.

In this connection the aims of the German and European energy policy cover three main issues:

- economy,
- security of energy supplies
- and environmental compatibility.

With enacting the directive on energy end-use efficiency and energy services (2006/32/EG) the European Union set itself the ambitious target to cut its energy consumption by 20% until 2020 and to reduce its dependency on imported oil and gas from other countries [1]. With this plan the EU could also cut down the CO2 emissions enormously. To achieve these aims the European member states are urged to draw up national action plans to achieve 1% energy savings yearly.

The German government reacted with the national energy efficiency action plan (EEAP) and the integrated energy and climate package (IEKP) [2]. Both programs cover different actions to increase energy efficiency in the fields of private and public households, industry and the traffic sector. Examples for such actions are the implementation of intelligent measurement methods for energy consumption (smart metering), energy management, communication and pricing systems [3,4]. In the view of these challenges it is mandatory to find effective and innovative solutions that are closely connected to the development of improved technologies. Thereby technical solutions for increased energy efficiency cover the consumption of the whole energy process chain, even the technical integration of the end consumer through information and communication technologies (ICTs) (cp. Figure 1) [5].

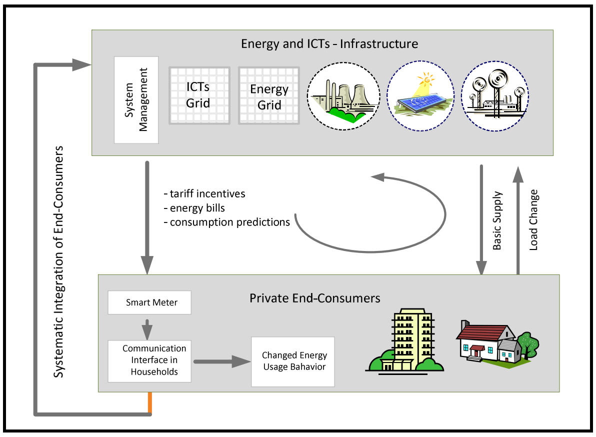


Figure 1: Systematic integration of end-consumers in the energy process chain

2. SMART METERING TECHNOLOGY

Closely connected to this is the amendment of the energy economics law in 2005. The amendment changed the legal framework in the field of counting and measuring electricity fundamentally and with the liberalization of measurement the way for competition to replace technologically outdated electric meters by new “intelligent” ones was cleared. The new approach involves innovative methods of measuring energy consumption by modern smart metering systems or AMM systems (Advanced Metering Management). Apart from the possibility of providing remote readout the new meter generation further has additional functions: On the one hand they enable a bidirectional communication by means of either a separate or an integrated communication system. The communication interface can either readout save data on energy consumption at intervals of every 15 minutes in one direction or communicate information to the meter in the other direction [6].

Since the AMM-systems provide a base technology for connecting further information and communications technologies it is possible to connect consumer information displays and interfaces to intelligent household appliances. Through the installation of the smart metering technology in private households consumers can receive information on their energy consumption and energy costs in real-time. At the same time the new technology is important for future concepts of intelligent networks, which have to deal with an expansion of renewable energy sources and decentralized supply in the energy distribution network. In this context the smart metering technology allows providers to issue various tariffs by daytime or system load and to send price signals in order to manage the inelastic demand more strongly and to react more efficient on the discontinuous supply of wind energy. But legal requirements as well as system integration of the end consumer using smart metering systems and consumer information systems are not sufficient to increase energy efficiency and to exploit the whole saving potentials of fluctuating wind energy supply. To display the entire effectiveness of the technical solutions it is necessary that consumers actively participate in the energy process chain and change their energy consumption behavior following a desired pattern.
In the end a more effective use of renewable energy can only be realized by a changed energy consumption behavior. This allows for supplying more renewable electricity and to achieve significant energy savings effects. However the understanding of the principle of the system solutions and the end-consumer being involved in the system himself is only adapted slowly by end consumers. Especially a missing awareness for energy complicates acceptance and usage of the new technology.

3. RESEARCH OBJECTIVES

The described problem was the starting point for an investigation focusing on the systematic integration of end-consumers to increase the energy efficiency of the entire power system. In the presented study the systematic integration refers to as an innovative customer interface in private households that is connected with a smart metering system. According to previous considerations this interface has several informative and communicative functions, for example presenting data on energy consumption and receiving price signals. The aim of such a consumer interface is, in the first place, to make energy consumption more transparent and understandable, and, in the second, to encourage energy awareness and energy-saving behavior. But even the success of an information interface yields the question of an optimal consumer-friendly design and finally broad consumer acceptance. Following this argumentation it is necessary to analyze how to design such a consumer interface. For that reason the main interest of the empirical study can be summarized with the following research questions:

- *How to present data on energy consumption on the consumer interface?*
- *What are the consumers’ expectations towards the interface?*
- *To what extend do technical requirements meet consumers’ demands?*

Based on these questions it is the intention the presented field study to design different instances of visualization of energy consumption data as an application for a mobile interface. In addition it was the aim to consider technical as well as social requirements of potential users of the application. In the context of smart customer technologies an Apple iPod touch [7] was used to provide a basis for a mobile interface that receives data from a smart meter, for example via WLAN in the household. That communication infrastructure can be exemplified as follows (cp. figure 2).

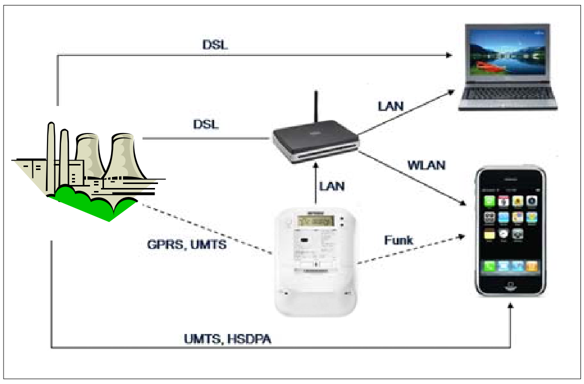


Figure 2: Smart metering communication infrastructure

The realization approach has been based on a User-Centered-Design [UCD] process that focuses on needs, wants, expectations and limitations of the end user [8,9]. According to Keinonen User-Centered Design is defined as “a broad umbrella covering approaches such as traditional human factors and ergonomics, participatory design, human-centered design, usability measurements and inspections, and design for user experience” [10]. The international standard for many UCD methodologies are based on the ISO 13407 [11] that characterizes the general process for including human-centered activities through a product development life-cycle, but does not specify exact methods. Based on the UCD process according to Bias and Mayhew the project covers four phases to design an end-customer-centered application for visualizing energy consumption on a mobile interface: Analysis, Design, Implementation and Test, here realized a User Experience Study [9]. In the following the previous results and actual status of these staged will be described.

4. REQUIREMENTS FOR THE MOBILE APPLICATION

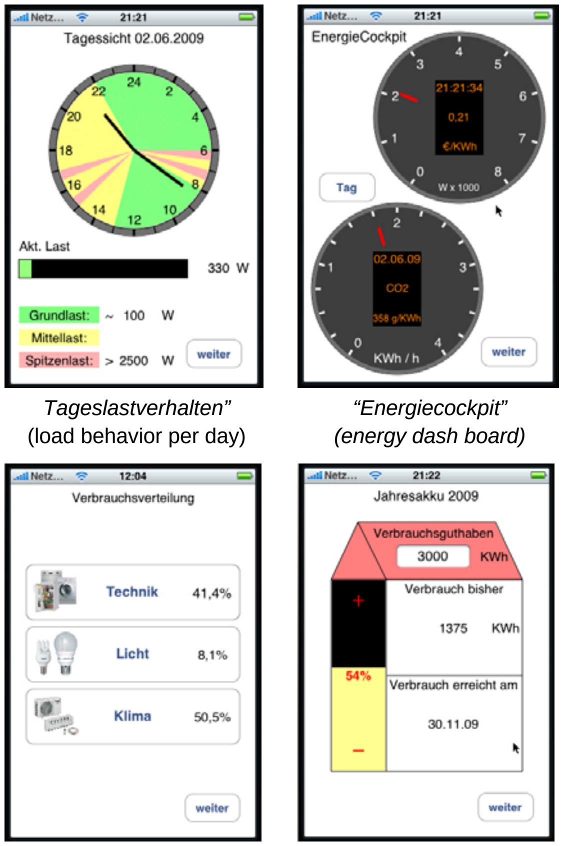
At first a comprehensive requirements analysis for applications on mobile interfaces regarding technical and creative requirements was conducted. Concerning the basic design first requirements were deducted from the "eight golden rules" for traditional interface design after Shneiderman (1998): (1) strive consistency, (2) universal usability, (3) offer informative feedback, (4) closeness in design dialogs, (5) Offer error prevention and simple error handling, (6) permit easy reversal of actions, (7) support internal locus of control and (8) reduce short-term memory load [12]. These rules are often a first suggestion in the development of interactive products. In this context these rules also provided a basis in the research project IKAROS to develop a guideline for designing interfaces surfaces on mobile devices. As a result aspects of this guideline, regarding information presentation, use of colors and icons as well as the navigation, were taken into account to define the application requirements [13]. In addition further requirement were conducted from the results of other research projects on energy feedback systems [14, 15, 16, 17, 18]. Deliverable of the first project stage was a requirement list for the development and design of the mobile application in the second project stage (cp. table 1).

Table 1: Requirements for the Mobile Application

- Use simple and already known indicators for consumption
- Use simple display formats
- Use familiar perception schemes (colors, metaphors, logic)
- Restriction on essentials Information
- Bright background and high contrast using
- Seven plus/minus two information per screen
- Consistent use of colors for a better navigation
- Avoiding red-green and blue-yellow color combinations
- Symbolic use of colors as warning signals using
- Using familiar symbols
- Fast and simple Navigation
- Communicating the current position in the navigation
- Offer the possibility to get to the start menu at any time
- Usability of the application for any potential consumer
- Diagrams on consumption as simple as possible
- Separate diagrams for several household devices

5. DESIGN AND IMPLEMENTATION

On the basis of these requirements four visualizations of energy consumption were initially designed in theory and then implemented as a mobile application the *E-Monitor*, on the above mentioned hardware (cp. figure 3).



“Tageslastverhalten”
(load behavior per day)

“Energiecockpit”
(energy dash board)

“Verbrauchsverteilung”
(consumption distribution)

“Jahresakku”
(annual battery)

Figure 3: Visualization of the E-Monitor

6. USER EXPERINECE STUDY

As mentioned before the test phase is realized as a user experience study. In comparison to the cognitive and task-centered concept of usability user experience has a stronger focus on the user and his expectations and evaluations [11]. According to Hassenzahl and Tractinsky (2006) user experience [UX] "is about technology that fulfils more than just instrumental needs in a way that acknowledges its use as a subjective, situated, complex and dynamic encounter. UX is a consequence of a user's internal state […], characteristics of designed system […] and the context […] within the interaction occurs" [19].

Based on this definition the concept of user experience enables to analyze consumers' expectations and to what extend the application meets the consumers' demands based on their evaluation. To carry out the user experience study the first step was to develop appropriate measurement tools to collect data on users' expectations and evaluations. In theory potential users of the application E-Monitor could be any end-consumer and there is no specific target group. For that reason the user experience study was carried out with students at the Ilmenau University of Technology as one possible target group.

6.1. User Expectations

The first step was to identify general expectations of potential users towards an application visualizing energy consumption on a mobile interface. This was realized as a qualitative design interviewing 25 students from social and engineering sciences about their desired information, preferred presentation style and functions of the application. After a short introduction in the smart-metering technology and the function of mobile interfaces, the students were asked to spontaneously formulate their wishes and expectations. The students did not see the already implemented mobile application and visualizations.
Subsequently all statements were merged into one table and categorized with regards to content. The following three main expectation categories have been identified from the students' statements:

- kind of information on energy consumption,
- layout of the presented information and
- additional functions of the application.

For a quantitative measurement of users' expectations these categories and the related statements have been put into a standardized questionnaire. It measures the users' expectations as importance of the different criteria by using a 5-point rating scale from "very important" to "very unimportant" [20].

6.2. User Evaluation

For the users' evaluation of the mobile application and the visualizations it was the next step to identify evaluation criteria and then to develop a measuring tools for the evaluation. The identification of evaluation criteria was based on two sources: Some general criteria were conducted from the requirements for the mobile application (cp. table 1).

At the same time a qualitative preparatory study with five students to identify further criteria has been carried out. The participants have been asked to evaluate one of the four visualizations in comparison to their expectations. The evaluation has been referring to layout, potentials of the application to support energy savings and supposed usage frequency. The idea of the study was on the one hand to receive information on conformity among the developed application and user expectations. On the other hand it was the intention to get a first appraisal of the usefulness of the applications as a feedback instrument on energy consumption from a users' perspective.

The results show that especially the previously selected names for the four visualizations did not meet the participants' expectations. The application names were not significant enough and so the volunteers had no idea what kind of information presentation they would expect. In particular the name "energy dash board" proved to be misleading, because possibilities of control and entering were expected. Furthermore the layout was evaluated as little attractive and too complicated. Moreover the name "consumption distribution" is still insufficient, since this name only illustrates a part of the functional range.

Here the application name should haven be chosen that would have covered the range. Regarding the choice of one visualization "consumption distribution" turned out to be the most preferred one. The group believed that this one has the highest potentials to achieve energy savings among consumers. In terms of utilization frequency they believed that "consumption distribution" and "annual battery" will be used most frequently. These findings have been used to identify further criteria mobile application evaluation, especially regarding the naming.

For a quantitative measurement of users' evaluation of the four visualizations the identified criteria were put into a standardized questionnaire. For the evaluation itself a 5-point rating scale ranging from "I agree at all" to "I do not agree at all" was used on the dimensions names, presented information and layout.

6.3. User Experiences with E-Monitor

For the analysis of user experiences with the E-Monitor both measuring tools were put together into one questionnaire that covers the expectations of potential users in the first part and the evaluation of the four visualizations in the second part. The user experience study was carried out as an online questionnaire. For the data collection in June 2009 students from the Ilmenau University of Technology were asked to complete the questionnaire.

7. RESULTS

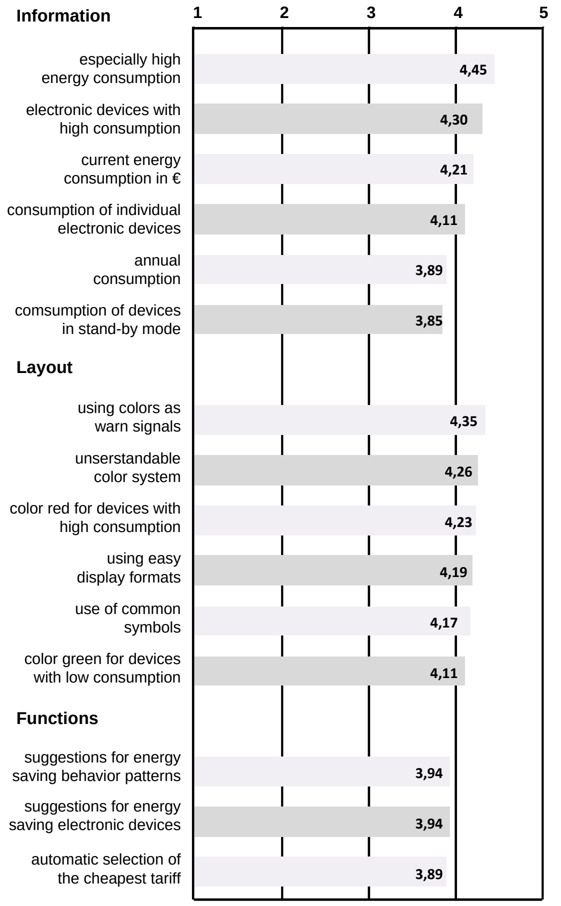
A sample of N=48 (62% female, 38% male) undergraduate students took part in the online survey. The demographic statistics indicated an age ranging from 19 to 35 years with a mean age of M = 23.3 years (SD = 2.8) years. To collect data on relevant technical equipment participants were asked about their flatrate accesses as well as iPhone and iPod touch possession: The results showed that 94% had a flatrate for DSL, 50% for a landline phone, 21% for a mobile phone and 4% had a data flatrate. Only one student had an iPhone and two students an iPod touch. Based on this it can be assumed that the respondents were short on experiences with mobile applications on Apple products. Referring to general interest in technologies and energy consumption the results showed that 42% of the students had a high interest in technologies and 29% in energy consumption.

7.1. Findings on User Expectations

Referring the required information of the mobile application the most important information for the potential users turned out to be general information on height, current and annual energy consumption on the one hand, but also more detailed information on energy consumption of single electric devices The findings on the preferred layout of the presented information showed that simplicity of display format, familiarity of used symbols and colors as well as a consist use of colors were most important for the students. Results on additional functions of the application showed that the most important ones regard to functions to reduce energy consumption and energy costs (cp. table 2).

In summary it turned out that the users' layout expectations converged the requirements for the mobile application analysed in the first project stage (cp. table 1). However it turned out that the really innovative and thinkable functions of the mobile application such as remote readout of smart meters (M=3,21) and remote control of electronic devices (M=3,02) were less important.

Table 2: User Expectations towards the Mobile Application



Measured on a 5-point rating scale (1 = very unimportant to 5 = very important)

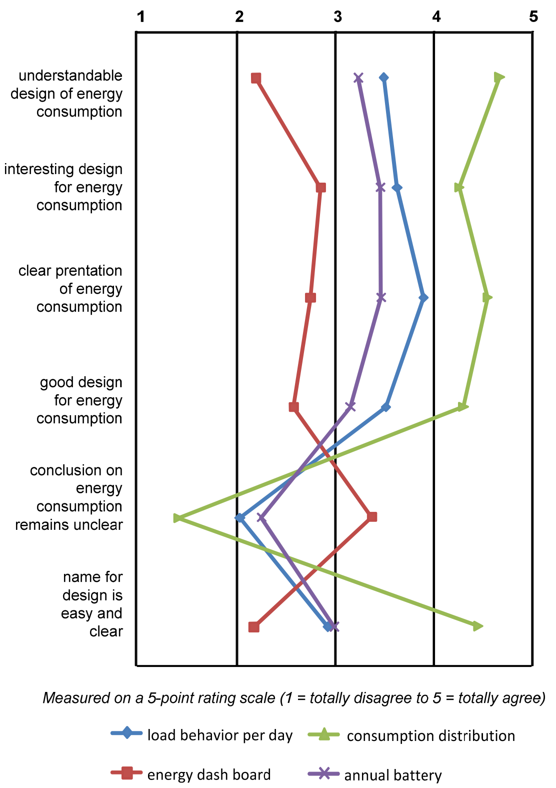
7.2. Findings on User Evaluation

For the general evaluation of the mobile application the users were asked about the best visualization, understandability of the application names and the usability. The results showed that 54% liked the visualization "consumption distribution" best, 33% "load behavior per day", 6,5% "annual battery" and also 6,5% did not prefer any of the four visualizations. Especially notable was that no one liked the visualization "energy dash board" best. In contrast to that the findings on understandability of the names for the applications were very interesting: Although the visualization "consumption distribution" was most liked one, only 2% said that this name for that application was totally understandable for them. In the case of "load behavior per day" it was also only totally understandable for 6%. On the other hand "energy dash board" was totally understandable for 27% and "annual battery" for 23%.

Referring the usefulness of the application 67% believed that the application has potentials to support permanent changes in energy saving patterns and 26% saw potentials to achieve short-term changes. Referring to a supposed usage frequency of the application 39% would use several times a week, 24% once a week and 6% every day. Only one student said that he would never use the application.

For the specific evaluation of the four different visualizations of energy consumptions some selected results are presented on the following table (cp. table 3). The results on user experience over all visualizations of energy consumption showed that "consumption distribution" was for the users the clearest as well the most understandable and interesting application. They also totally disagreed that the conclusion of that visualization on their energy consumption remains unclear what concurred to the earlier findings that this application is the most referred one. In contrast the "energy dash board" had the worst evaluation. For the users this design was little understandable and interesting and the name of the design not even clear.

Table 3: User Evaluation of the four Visualizations



Measured on a 5-point rating scale (1 = totally disagree to 5 = totally agree)

8. CONCLUSION

In summary, referring to the aim of consumer interfaces to make energy consumption more transparent and understandable to increase energy efficiency in private households, the results underline the importance of a consumer-friendly design to make such interfaces effective. The findings showed that the users' expectations towards such an interface and their evaluation can differ quite clearly. It also revealed that the potentials of a user interfaces to encourage energy awareness and energy-saving behavior are, as supposed, a question of an optimal and finally broad consumer acceptance and that there are still al lot of interesting issues for further research in the field of systematic integration of end consumers by using innovative interfaces.

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