

Motivating Domestic Energy Conservation through Comparative, Community-Based Feedback in Mobile and Social Media

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ABSTRACT

The progress of technology has led to the increased adoption of energy monitors among household energy consumers. While the monitors available on the market deliver real-time energy usage feedback to the consumer, the format of this data is usually unengaging and mundane. Moreover, it fails to address consumers with different motivations and needs to save and compare energy. This paper presents a study that seeks to provide initial indications for motivation-specific design of energy-related feedback. We focus on comparative feedback supported by a community of energy consumers. In particular, we examine eco-visualisations, temporal self-comparison, norm comparison, one-on-one comparison and ranking, whereby the last three allow us to explore the potential of socialising energy-related feedback. These feedback types were integrated in *EnergyWiz* – a mobile application that enables users to compare with their past performance, neighbours, contacts from social networking sites and other *EnergyWiz* users. The application was evaluated in personal, semi-structured interviews, which provided first insights on how to design motivation-related comparative feedback.

Keywords

Energy monitoring, environmental sustainability, sustainable HCI, comparative feedback, persuasive applications, urban informatics, social networking

INTRODUCTION

The ongoing processes of climate change are fuelled by the growing industrial and residential carbon footprint. While industry's contributions to greenhouse gas emissions can be

limited by regulatory legislation, the energy consumption of domestic households is difficult to regulate without engendering dissatisfaction among residents. Therefore, local governments started promoting energy efficiency through programs, such as the *Climate Smart Home Service* program of the Queensland Government in Australia [36]. While such programs may increase energy efficiency through technological means, for example offering compact fluorescent lights (CFL), they also try to influence consumer behaviour by introducing home energy monitors. Utility-driven initiatives for deploying smart meters in the residential sector also gain momentum, e.g., in Germany [48] and USA [43]. With this new source of real-time energy usage data, consumption is expressed as cost, kilowatt hours (kWh), or carbon dioxide (CO₂) emissions. The display of this data helps some users to conserve energy with the prospect of saving money. In case they achieve significant cost savings, they will probably find new ways to consume the “saved” energy, which is known as *Jevons's paradox* [34]. However, if people are motivated to live in a more environmentally conscious way, they will possibly require feedback about their impact on the environment expressed in units of CO₂ emissions. Since energy is just as invisible as CO₂ for them, the energy saving process is rather complex: first, users have to make sense of the measurement units, second, find out if they are efficient or not, third, think about proper actions which will lead to reducing energy use. This ultimately leads to significant cognitive overload. When faced with such mental demands of choice, people begin to rely on irrational methods for dealing with them [45] that often result in inefficient energy use.

Additionally, most energy monitors provide the same feedback to all users: “one-size-fits-all” [31]. Different motivations are not taken into account. Along with this, in

our interconnected world of social media, energy saving still remains a lone activity.

The goal of this study is to address these issues by providing first indications about characteristics of effective, motivation-specific design of comparative feedback on energy use for consumers with different motivation concerning energy conservation and comparison. Furthermore, we would like to explore the potential of socialising energy-related feedback. The research process is facilitated by an Android-based mobile phone application called *EnergyWiz*.

The paper is structured as follows: First, we focus on environmental and social psychology to determine the relevant properties of energy-related comparison. Thereafter, we review related work about each relevant type of comparative feedback while focusing on motivating behaviour change. Next, we describe the design of *EnergyWiz*, and present an overview of its architecture. Prospective users evaluated our application, and their feedback is summarised in the findings section. In the end, we discuss the implications that our research can have on the design of *EnergyWiz* and other similar applications as well as its limitations.

RELATED WORK

Sustainable HCI

With increasing public interest in climate change, environmental sustainability has become a prevailing topic in the field of Human-Computer Interaction (HCI), a trend which DiSalvo et al. [12] call “Sustainable HCI,” that is, research at the intersection of people, technology, and environmental concerns. A considerable part of this research is devoted to persuasive technology [20] that aims to motivate people to live in a more sustainable way [12]. Often unaware of it, designers of persuasive applications are sometimes led by assuming a certain model of human pro-environmental behaviour when designing for a specific user type [23].

Models of Pro-Environmental Behaviour

In an attempt to understand why people adopt pro-environmental behaviours, environmental psychologists employ predominantly two views – the *Rational-Choice Models* and the *Norm-Activation Models*. The former imply that environmental behaviour is primarily driven by self-interest [23] and assume that people are motivated to avoid punishment and to seek rewards [3]. Conversely, the Norm-Activation Models view pro-social motives as most important (such as avoiding conditions that might cause threats to others) and rely on the basic premise that moral or personal norms are direct determinants of pro-social behaviour [3].

Although these models provide explanations for people’s motivations for acting pro-environmentally, they do not give specific advice on how to support people in doing so. The specific motivational techniques are those that embed design goals into a tangible prototype. In our study, the motivational technique we focus on is comparative feedback, which, as the name suggests, employs two

motivational techniques established in psychology – feedback [26] and comparison [23].

Feedback

Feedback is information that provides a basic mechanism with which to monitor and compare behaviour, and allows an individual to better evaluate their performance. Feedback is one of the most effective strategies in reducing energy consumption at home [24]. In a comprehensive meta-research study, Darby has found that feedback on energy consumption at home can lead to up to 15% in energy savings [11]. Although providing energy-related feedback is somewhat effective, most of the employed techniques are limited as they tend to use a “one size fits all” approach which means that they provide the same feedback to different individuals who have different motivations and experiences in energy saving [31].

Energy-related feedback information is conveyed to a person through a visualisation device and is produced from the constant collection of data relating to the level of resource consumption [44]. Recent advancements in energy metering technology and various energy efficiency policies have engendered mass deployment of advanced metering infrastructure (AMI), which communicates the energy consumption of households over a network, and therefore enables the provision of automated, real-time feedback about energy consumption. Along with this trend, social media sites, such as Facebook and MySpace found wide adoption, which provided new opportunities for communicating energy-related feedback. Several works have already laid the foundation in the research on socialisation of energy feedback. Mankoff et al. [39] first proposed employing online social networks to motivate reduction in energy consumption, whereby they integrated energy-related feedback into the profiles of MySpace users. Later, their idea evolved to StepGreen.org – an online community built to promote energy-saving behaviours employing public commitment and competition [38] strategies to motivate users. In another study, Foster et al. [22] developed a Facebook application that delivered energy-related feedback integrated in social context to eight households that reduced their energy usage significantly due to socially mediated encouragement and competition.

These studies show the potential of socially enabled comparison. In this paper, we go one step further by looking into the different types of comparison and using them to make energy saving at home more engaging and, ultimately, motivate behaviour change towards energy-efficient lifestyles.

Comparison

Comparison can be *temporal*, i.e., contrasting one’s achievements to past performance, or *social* – comparing them to those of others. Comparative feedback (i.e., the feedback that contains some type of comparison) is a motivating factor in persuasive applications that promote behaviour change in areas such as energy conservation or healthy lifestyle [10, 22, 38]. We now review previous research into comparative feedback that we divided into

three groups: *explanatory comparison*, *temporal comparison* (self-comparison feedback), and *social comparison* (consisting of normative, one-on-one, and comparison by ranking feedback types).

Explanatory Comparison (Eco-Visualisations)

Comparison is often used for explaining energy use whose invisible character makes it complex for the energy consumers to perceive their consumption. Especially, it is difficult to relate energy consumption to the negative consequences for the environment [44]. One attempt to overcome this hurdle is the implementation of eco-visualisations, which are “real time consumption statistics of key environmental resources for the goal of promoting ecological literacy” [32]. They might represent energy usage in terms of, for instance trees needed to compensate for the generated CO₂ emissions. While some of the eco-visualisations are artistic, animated works such as “7000 oaks and counting” [32], others deliver the same information in a more pragmatic way through text or images, e.g., eMeter Home Energy Dashboard [53].

Temporal Comparison

The *Temporal comparison theory* defines temporal comparison as the act of an individual comparing herself at two different points in time [2]. In the field of HCI, temporal comparison is most often depicted in charts over a certain period of time aimed at satisfying user’s need for self-evaluation and learning.

Previous research on self-comparison feedback found that the comparison of individual’s achievements in the past with current performance is effective in motivating action, especially when assuming the previous consumption levels were lower than the present [5]. Such information can show significant trends in behaviour (e.g., energy consumption or frequency of physical activities) over various periods of time that result in users’ reflection about the reasons for the particular behaviour and the context in which it took place.

With regard to energy conservation, Fitzpatrick et al. [19] documented that such comparison is often accompanied by playful explorations of the energy consumption data and increased awareness about normal usage patterns for everyday situations. Moreover, a focus group study in the UK found that there was an “overwhelming preference for simple comparison of historical data” [46]. However, Egan [14] stated that self-comparisons pose significant limitations because of their scope since they consider only the individual’s behaviour and disregard its relative position among those of similar individuals or households. Although it can be useful to detect anomalies in one’s personal energy usage patterns, it is a poor indicator of fundamental problems in the energy consumption [14].

In studies aimed at motivating physical activity, users reported that self-comparison decreases the mental load of tracking their historical performance and thus increases usability of the application and their motivation [10].

Social Comparison

In his *Theory of Social Comparison Process*, Festinger [17] hypothesised that people evaluate their abilities through

comparison with the abilities of other individuals (comparison targets) whereby the tendency to compare oneself with another person decreases as the difference between their abilities increases. Moreover, recent research in social psychology has shown that assimilation (i.e., compliance with achieving a set target) can happen in case the comparison target shares common personal characteristics with or has similar experiences as oneself. On the other hand, desire to contrast oneself and a target can appear in absence of that similarity [51].

According to previous research, in some cases feedback on energy usage of other people appears to be more effective in motivating conservation than temporal self-comparison [33]. This might be the case since social comparison facilitates competition thus tapping into user’s intrinsic drive for cognition and extrinsic need for social status (social recognition) [54]. Motivation could also be achieved by pressure through social sharing [41] and social validation that is expressed in human’s unconscious strive to comply with the actions of like-minded individuals [9, 54]. In the context of energy conservation, social comparison may be especially effective when relevant others are chosen as comparison targets [1].

Feedback containing social comparison (i.e., social feedback) is influenced by various comparison factors determining the type of social feedback. Grevet [29] documented five types of factors:

1. Cardinality of the comparison (individual vs. individual, individual vs. group);
2. Group membership (in-group, group vs. group)
3. Anonymity;
4. Number of comparison dimensions;
5. Interaction type (competition or collaboration).

In our study, we concentrate on cardinality of comparison and anonymity to build three types of social comparative feedback: normative, one-on-one, and ranking. They represent exclusively in-group comparisons over one comparison dimension and support, where possible, both competition and collaboration.

Normative Comparison Feedback

Comparing with a norm (i.e., a reference value or benchmark) is a type of social comparison in which an individual or a group is compared to an averaged performance (statistically) of similar subject, for instance neighbours’ or classmates’ performance. Previous research has not unequivocally proven its effectiveness.

Normative messages put in hotel rooms saying, “The majority of guests in this room reuse their towels.” increased the likelihood of towel reuse by hotel guests by 33% [28]. Such a normative comparison was successful because it addressed one’s immediate circumstances, i.e., it was contextualised. Fischer [18] examined twelve studies on motivating energy conservation through normative comparison. None of them were able to demonstrate any effect on energy consumption. This research found that – while stimulating above average consumers to conserve – users whose consumption was below average still had room

to increase their consumption (the “boomerang” effect). Another study done by Jensen confirmed these results [33]. Schultz and his team [49] addressed this issue in a field study of Californian households. They found that adding a message of social approval or disapproval (injunctive message) to the normative one eliminates this effect thus decreasing the overall energy consumption.

Another problem with normative comparison is to find suitable “others” whom consumers should compare with. Two studies conducted in the UK [19, 46] discovered that people preferred self-comparison to normative comparison since they were not satisfied with their assigned group.

One-on-one Comparison Feedback

One-on-one comparison is, as the name implies, comparison between two individuals. As stated by Festinger’s theory of social comparison, the tendency to compare with someone decreases as the difference in their abilities or opinion increases [17]. Since it is difficult to convince a person that the abilities of a particular unknown other are the similar to theirs, meaningful one-on-one comparison may involve closely related people (e.g., friends, classmates, colleagues). So, the participants will be tempted to compare due to the personal contextualised nature of the comparison.

In an energy saving competition between two departments in a metallurgy company, the department which had access to others’ consumption data, achieved higher energy savings [50]. Positive results were also achieved in a research aimed at increasing physical activity among friends through one-on-one comparison [10]. In contrast, similar studies that offered comparison with anonymous people or strangers were not successful [25, 40].

Comparison by Ranking Feedback

Rankings usually depict competitions among individuals or groups and explicitly order them depending on their performance. Unlike the one-on-one comparisons, rankings are suitable for long-term competitions and present a viable option even when the participants are not closely related but still share much common context. Similar to the previous comparison type, ranking as a strategy is largely unexplored when it comes to motivating energy conservation and previous research on it provided mixed results [8].

In a dormitory college competition on energy conservation at Oberlin College, Ohio, student teams were motivated through ranking and reduced their energy consumption by 32% in total [42]. The competitiveness of rankings also motivated a study group of women to walk more [10] and addressed even the poor-performing ones (none of whom wanted to be ranked last). However, a comparable research project did not show any increase in the targeted behaviour because users disliked the competitive element [4] which further supports the ‘one size does *not* fit all’ hypothesis.

The review of previous research on motivating behavioural change through comparative feedback has shown that while significant results can be achieved in some of the studies, in others this is not the case. The reason for this might lie in

the fact that the comparison targets (norm and direct) were unsuitable, the feedback was not contextualized, or the extreme performers lost interest. Additionally, different studies delivered different results in spite of the similarity of the provided feedback, supporting the notion that one design is not suitable for different users, i.e., “one-size-fits-all” solutions fail to address the individual needs of each user by providing the same feedback to “differently motivated individuals at different stages of readiness, willingness and ableness to change” [31].

RESEARCH DESIGN

We chose to focus this study on the concept of comparison because it is still largely unexplored in the context of energy conservation [55], although the majority of persuasive applications provide comparative feedback and it represents a promising way to socialise the process of energy saving.

Research Question

This paper addresses the research gap found in the literature review concerning how energy-related comparative feedback should be designed, so that it addresses users with different motivations. In particular, our work aims at providing initial clues about design guidelines for each comparative feedback type considered above.

As it has already been discussed, people have different motives that drive them to save energy and compare with themselves or with others. This means that we can expect that differently designed comparative feedback types will appeal to different individuals. To maximise the benefit of the mentioned comparative feedback types, we will interpret our findings based on the different motivations of the users.

The present study further explores the potential of motivating domestic energy conservation by embedding comparative feedback in social media, specifically, Facebook.

METHODOLOGY

Our approach to the research question consisted of developing the mobile application *EnergyWiz* and using it as a foundation for discussion with prospective users. The first step was to build *EnergyWiz* using a theory-driven design approach [6], whereby our focus was exclusively on comparative feedback.

Following the development activities, we organised personal, semi-structured interviews with 17 prospective *EnergyWiz* users. 14 of them were male and 15 of them between 25 and 34 years old, the rest were slightly younger or slightly older. 14 were full-time employees while the others were full-time university students. The goal of this user study was to gather qualitative feedback about each of the comparative feedback features of the application, which would contribute to the derivation of motivation-specific design guidelines.

The interview process was two-fold: First we conducted an application walk-through with all participants by giving

them meaningful tasks in the form of scenarios, whereby the interaction was recorded with a camera.

After the walk-through, we conducted individual, semi-structured interviews. Their primary purpose was to gather information about participants' motivation to save energy and to compare. Along with this, we were also interested whether they had prior experience with energy conservation and online social networking sites. Once a detailed picture of these characteristics was available, we proceeded with a systematic review of each comparative feedback type where the participants' role was to think about which motivation for comparison relates to each type of comparative feedback. Then, they also commented on how they would have designed the particular feedback type differently. Based on the comments and users' personal characteristics we planned to construct our suggestions for motivation-specific design guidelines. To ensure that the results are tangible, we looked at particular types of motivation derived from our review of the theory.

Due to the fact that comparison is inherently available in all of the feedback types of *EnergyWiz*, we assumed that user's motivation for comparison would be one of the factors that will have significant influence on the preferred feedback design (Characteristic 1). Research in previous works in the field of social comparison theory led us to the following list of possible motivations for comparison:

- Evaluating abilities [17] (Benchmark)
- Self-enhancement [17, 30] and Maintaining positive self-evaluation [52] (Learning and Improving)
- Competition / Need for cognition [7, 54]
- Curiosity [37]
- Social validation [27] (doing what similar people do)
- Recognition/ appraisal from others [47]

Another key determinant of the preferred feedback design was expected to be the motivation to conserve energy (Characteristic 2). The models of pro-environmental behaviour established in environmental psychology propose that people undertake pro-environmental actions because of personal benefits, pro-social intentions or both [23]. We used a concrete motivations list based on the models which resulted from a representative study among energy consumers [35] and included the following motivations: someone asked me to, people I care about are doing it, other people approve when I do it, it makes me feel good about myself, it is the moral thing to do, it helps reduce global warming, it saves me money.

Additionally, other personal characteristics, which also showed a significant level of influence on energy saving through *EnergyWiz*, were previous experience in energy conservation (we defined the labels "experienced," "inexperienced," "no experience"), and usage of online social networking sites (Characteristics 3 and 4).

Finally, we invited 7 experts with extensive experience in mobile and social applications to discuss *EnergyWiz*, all of them being young males, below 40. They helped us define the challenges before *EnergyWiz* as a mobile, social energy monitor application.

In summary, the findings of this research were framed as "clusters" of considerations for each of the four personal characteristics we enlisted above. They contained suggestions on how comparative feedback types could be designed based on the knowledge gathered through the personal interviews with our participant group and the experts.

APPLICATION DESIGN

We developed *EnergyWiz* as a fully functional prototype of a mobile application for energy monitoring that is Facebook-enabled and combines the five types of comparative feedback, which were examined in the related work section. Our main goal during the design process was to motivate energy conservation at home by addressing issues found in previous research and overcome those functional shortages. Among the user benefits we wanted to emphasise on through comparison are: providing realistic benchmark for energy consumption; integrating energy consumption information in a social context and engendering a discussion among the user community; explaining energy use by non-social comparison; making energy-related feedback accessible on a mobile device.

The major features of *EnergyWiz* (corresponding to the mentioned five comparative feedback types) are "Live Data," "History," "Neighbours," "Challenge," and "Ranking," representing rather diverse comparisons (Figure 1 left). Their combination in one application allows us to examine which motivations were addressed by each feedback type. Further, with the help of user studies, our longer term goal is to derive design guidelines for each feature, which will maximise the benefit they each deliver.

The initial version of the application was designed based on a theory-driven approach where all design decisions were made exclusively using the fundamental theories of social comparison and pro-environmental behaviour as well as findings from previous research in the field.



Figure 1: *EnergyWiz* Main Menu and Live Data

The Live Data feature presents the current energy consumption in the household (Figure 1 right). We included it in the application because in previous studies, participants have shown interest in real-time consumption data [8, 11, 19]. Moreover, in another study, providing real-time data turned out to reduce the energy consumption by almost 13% [13].

Our design of real-time feedback allows the user to switch between different units of energy consumption – kWh, kg of CO₂ and money. As Wood notes, “the units of display can have a powerful influence on the consumer as they effectively dictate the comprehension” [55]. From a theoretical point of view, different information presentation is associated with different models of pro-environmental behaviour [23] and with experience level in energy conservation. One of the presentations we use is the objective raw amount of energy consumed during the last minute which we thought will engage inexperienced users in playful exploration [19]. Another element of the live data section was the scale which displayed the level of efficiency of the current energy use inspired by the need to interpret the raw consumption numbers [55]. To connect to the material impacts of the consumption [8,44], we employed an explanatory comparison depicting the consumed energy amount (i.e., number of trees needed to compensate the generated CO₂ emissions).

Another feedback type that we included the temporal comparison (“History”), because Albert [2] proposed in his *Temporal Comparison Theory* that there is a human drive to evaluate oneself through self-comparison over time. In addition, there is evidence that such feedback is preferred [46] since it provides a tool for analysis and insight [44] which leads to competence gain over time [31].

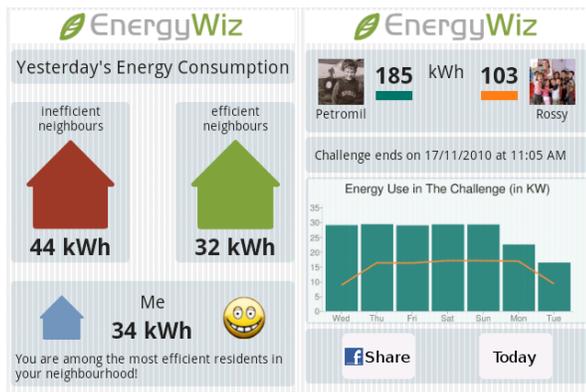


Figure 2: EnergyWiz Neighbours and Challenge

Motivated by people’s intrinsic tendency to compare with other people [17], the rest of the *EnergyWiz* functionality is focused on social comparative feedback. For all three different comparison features we were led by the premise that the comparison targets, i.e., the people whom users compare with, should be relevant and similar to them [17, 51]. Hence the Neighbours feature, where one can compare themselves to two groups (efficient and inefficient neighbours) (Figure 2 left). The relevance of the neighbours lies in the exposure to the same local weather conditions and the probable similarity of household type. These arguments might overcome the dissatisfaction related to comparison with national averages [19, 46]. Additionally, to overcome the “boomerang effect” [18], we added an injunctive message in form of a smiley [49].

Still, we were determined to explore social comparison further by providing even more relevant comparison targets

and make the users feel they are part of an energy-saving community. The approach we took was building comparisons on top of the user’s social network in the popular social networking site Facebook [16]. In order to create engaging feedback, *EnergyWiz* lets the user “challenge” a Facebook friend of theirs on a weeklong energy saving competition (Figure 2 right). Our inspiration came from the promising results of previous studies that showed people’s willingness to compete in online social networks [22, 38] and compare with real and known people [1, 20]. During the challenge, users are able to post the current score to their Facebook wall. Such public posts can boost the commitment of both parties [24, 41], leading to discussion among the people who comment on the posts or even make them save energy following the example of their friends [9, 54].

The second Facebook-enabled comparison we introduced is a ranking among similar *EnergyWiz* users (in terms of household and residence type) that connected their Facebook account with *EnergyWiz*. Its daily updates take into account the consumption in the last seven days and aim at motivating long-term engagement. Here, the comparison targets are similar *EnergyWiz* users, mainly because similarity between Facebook friends is not always given. Moreover, we would like to explore the idea of a Facebook community of *EnergyWiz* users; therefore we designed weekly posts of the ranking to the wall of a dedicated *EnergyWiz* group in Facebook. This design decision was an attempt to show the users that they are not alone in energy saving and to facilitate discussion about energy saving which was assumed to have positive effect on users’ conservation behaviours [44].

TECHNICAL SETUP

So far we described the interface design of the *EnergyWiz* mobile application, which is only one of the three composite parts of the whole system, the other two being the server and the desktop application (Figure 3).

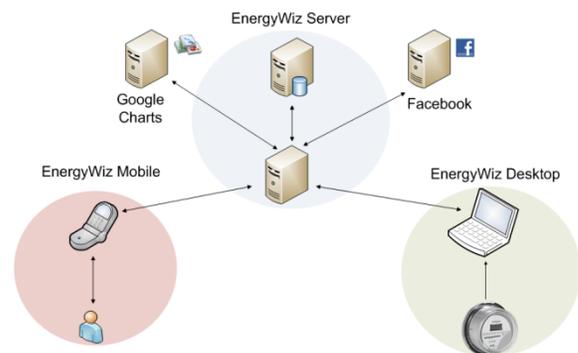


Figure 3: EnergyWiz Architecture

This distributed character is due to the fact that the information provision, the information management and the information consumption happen remotely and apart from each other. Another important reason is that we were committed to build a decoupled system based on open communication standards (RESTful web services) that will allow us to flexibly adapt parts of the system to the rapidly changing technology.

The first part of the system, the *EnergyWiz* Desktop plays the role of raw energy data provider. It employs off-the-shelf AMI that gathers approximated energy consumption data through a sensor clamp in the household's power box and transmits it wirelessly to a universal serial bus (USB) receiver connected to a personal computer (PC) at home. After the data is stored on the PC, a Java application reads it and sends it to the *EnergyWiz* Server.

The *EnergyWiz* Server provides centralised data storage for all system users and implements social comparison logic as well as analytics modules that allow us to better understand users' interactions with the application. The system consists of the Java Enterprise application server *Glassfish* and the relational database server *MySQL* whereby former connects to the Facebook Graph API (application programming interface) [15]. Through the API, we fetch social graph data and implement posts to users' walls. Additionally, the server also connects to Google Charts, which are a major part of the application. In summary, the *EnergyWiz* Server plays a central role in our architecture since it connects external parties, such as Facebook and the internal components: *EnergyWiz* Desktop and *EnergyWiz* Mobile.

EnergyWiz Mobile is the front-end of the system, and as mentioned above, the main point of user interaction. We chose to build a mobile application since it allows permanent, on-demand interaction and is not constrained by place as the static energy monitors usually are [21].

FINDINGS

The 17 individuals who took part in the semi-structured interviews provided us with detailed information about themselves and feedback concerning the *EnergyWiz* application. Our findings are structured according to the influencing factors we have already determined: (1) motivation for comparison, (2) motivation for saving energy, (3) experience, and (4) presence in online social networking sites.

Motivation for Comparison

Before going into the different motivations, we should note that all participants were of the opinion that temporal self-comparison (History feature) is a "must-have" function, so we concluded that it should be present no matter what users' personal characteristics are.

Benchmarking

The interviews have unequivocally shown that similarity between the user and the people they compare to in terms of consumption patterns is crucial. For instance, it has become clear that the Neighbours feature supports benchmarking but users expressed concerns about how similar their neighbours really are to them (stating they have different lifestyles, different home appliances, etc.). User 17 (U17) noted that similar people are more valuable for him as comparison targets for benchmarking, while U11 suggested using standard, averaged values for different activities, like doing laundry, etc. Still, there were some people who indicated that they live in homogeneous neighbourhoods where a certain level of similarity is given.

The Challenge feature is only partly seen as a benchmarking feature as it leaves the similarity estimation up to the user. To provide better benchmarking, some participants suggested comparing the reduced energy usage as a percentage value rather than as an absolute consumption value.

In contrast, the Ranking feature supports benchmarking as similar *EnergyWiz* users participate. Nevertheless, in order to provide benchmarking, we found that assigning a rank is not necessary, but a mere grouping based on efficiency is sufficient.

Learning and Improving

According to the interviewees, who see comparison mainly as a means to learn and improve, Live Data and History features provide the best learning opportunities. Above all, the former engages users in playful explorations of turning devices on and off to learn how a device impacts the total consumption. Another favourite of the participants was the explanatory comparison that illustrated consumption as a number of laptops, and CO₂ exhaust as trees. They were even willing to view more explanatory comparisons. In contrast to the Live Data feature, the History feature provided another perspective as an analytical tool to learn about consumption patterns such as day vs. night, weekdays vs. weekend, monthly and yearly comparisons.

The social comparison features did not provide much learning benefits according to the interviewees. One reason for this is that *EnergyWiz* did not offer a communication channel between the comparing parties in the application itself through which users could exchange tips (U9). Neighbours, Challenge and Ranking features are possible candidates for such integrated communication as long as similarity in the consumption patterns between the comparing parties is available.

Competition

All social comparison features provided competition functionality for the users but Neighbours and Ranking features attracted only part of the competitive interviewees. On the other hand, the Challenge feature was undisputedly their favourite. Obviously, friends are more preferred for competition than other similar users. In this regard, some individuals clearly stated that they would enter a competition only if their peers participated. Others expressed concerns about the fairness of the competition and suggested keeping permanent personal contact with the competitors or watching for fluctuations in their energy use to ensure they are at home during the challenge and not away on a vacation. Furthermore, there was a prevailing preference for kWh as a comparison unit because both money and amount of CO₂ are utility specific.

Curiosity

The majority of the interviewees were curious about how others are performing in energy saving. Neighbours and Challenge features satisfied their curiosity mainly because of the physical proximity of the former and the personal relationship of the friends. On the contrary, the Ranking

feature only partly supported curiosity probably because of the lack of sufficient context information.

Social Validation and Recognition (Appraisal)

In the preliminary interviews, none of the participants mentioned social validation (i.e., doing what similar people do) or recognition as their primary motivation for comparison. Therefore, we were not able to confirm their role in the design of persuasive energy-related feedback.

Motivation for Saving Energy

Users, whose primary motivation for conservation was saving money, were interested in energy consumption as amount of dollars, while those with pro-environmental motivation varied between kWh and amount of CO₂. These preferences were not only limited to the units but also to the explanatory comparison.

Experience

Another influential characteristic for the measurement units was the experience of the user in saving energy. The experienced users were comfortable with kWh and pointed out its objectivity whereas those lacking it, stucked mostly to the financial representation and only partly to CO₂. In addition, they found the efficiency scale valuable in providing them a justification for their performance.

Experience also has influence on competition, whereby the experienced, competitive users were willing to participate in a challenge right away. The inexperienced, however, preferred to wait until they gain experience (U14) or expected longer challenges during which they can learn (U16).

Social Network Presence

Three of the participants did not have Facebook accounts but nevertheless were willing to compete against friends, compare to other *EnergyWiz* users and even publish their consumption data. The majority of participants preferred the integration with Facebook but some of them were willing to share information only with their friends that are *EnergyWiz* users themselves since others would not have been interested.

DISCUSSION

During the interviews, we have noticed several recurring ideas and preferences from users. First, similarity between the factors contributing to energy consumption of the comparing parties is of considerable meaning for comparison in *EnergyWiz*. However it is a challenging task to find two identical households whose comparison will provide undisputable foundation for realistic comparison since even similar families in identical homes might have different appliances and lifestyles. A possible solution to this issue that emerged from users' interviews is to use user's relative energy saving toward previous consumption. Such an approach would have a diminishing effect on the difference. Another, complimentary approach suggested by Expert 4 (E4) in the expert interviews was to create targeted challenges, for instance "evening" or "weekend" in order to isolate some dissimilarities in lifestyle.

At this point it is interesting to note that our results suggest that when competing, our interviewees clearly preferred

friends to similar users or neighbours. This contrasts to the fact that when they used comparison as a benchmark or for learning, similar users were more relevant. In this sense, for *EnergyWiz* users, competition puts more emphasis on emotional, rich-context relationship than on similarity. So, depending on the particular user motivations, *EnergyWiz* should provide a mechanism for choosing relevant people for comparison.

Second, we found that *EnergyWiz* does not support peer learning very well. In the expert interviews, it became clear that "the last mile" to energy saving is missing, that is, personalised hints how to conserve energy. Social comparison features had the same disadvantage because there were no communication channels directly integrated in the application between the comparing parties. Therefore, in order to support learning, the application should better facilitate communication between users by implementing such mechanisms in future versions of *EnergyWiz*.

Third, due to the tight integration with Facebook, users who do not have a Facebook account but are willing to compete with friends or compare with *EnergyWiz* users remain dissatisfied. Others do not feel comfortable sharing challenge scores with all of their Facebook friends but only with those that are application users. This feedback led us to the idea to build our own *EnergyWiz* community, parallel to the Facebook integration. Such approach might help to recruit users without a Facebook account but could split the content generated by the users between the two communities. This issue requires further research.

Finally, a key point that evolved during both the user and the expert interviews is to entice people to use *EnergyWiz* over a longer period of time. This is a challenge for a mobile energy monitor since, in contrast to its static alternatives, the user must pro-actively launch it. Expert E6 suggested including an Android widget for users' home screen and alerts for anomalies in the energy consumption might serve as a reminder for the user to get back to *EnergyWiz*. Another way to keep users' interest is to explore social gaming dynamics, frequent flyer points and status schemes, and try to get even more from the integration with Facebook apart from wall posts and group discussions. In the expert interviews it became clear that getting points for reduction in consumption will not be effective on the long run since users will (hopefully) reach their acceptable minimum at some point. From then on, they will be unmotivated to continue playing. An incentive suggested by the experts was to introduce rewards such as "check-in" badges not only for curbing energy use but also for sustaining the progress.

LIMITATIONS AND FUTURE WORK

The predominant part of interviewed prospective users was young, full-time employed males. We are aware of the fact that all of our findings might not directly apply to other demographic groups. Nevertheless, we chose the user mix deliberately because we think it is highly probable that the first adopters of AMI will be young and technology-savvy

males. The next steps of the *EnergyWiz* study will be to redesign the application according to the presented findings and test it further in more detailed, long-term field studies.

CONCLUSION

In this research paper, we presented the mobile application *EnergyWiz* to potential users and, based on their feedback, derived initial motivation-specific design insights for comparative feedback. We explored different opportunities to socialise energy-related data in order to foster discussion and give a sense of community of users interested in reducing their energy consumption. In summary, our work is a first step in breaking the “one size fits all” paradigm and filling this research gap by designing comparative feedback for energy users with different motivational strategies that respond to different levels of experience.

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