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A Customisable Dashboard Display for Environmental Performance Visualisations

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Abstract. We conducted an exploratory study of a mobile energy monitoring tool: The Dashboard. Our point of departure from prior work was the emphasis of end-user customisation and social sharing. Applying extensive feedback, we deployed the Dashboard in real-world conditions to socially linked research participants for a period of five weeks. Participants were encouraged to devise, construct, place, and view various data feeds. The aim of our study was to test the assumption that participants, having control over their Dashboard configuration, would engage, and remain engaged, with their energy feedback throughout the trial. Our research points to a set of design issues surrounding the adoption and continued use of such tools. A novel finding of our study is the impact of social links between participants and their continued engagement with the Dashboard. Our results also illustrate the emergence of energy-voyeurism, a form of social energy monitoring by peers.

Keywords: energy monitoring, environmental sustainability, persuasive technology, domestic environments, households, urban informatics

1 Introduction

This research project investigates the potential of real-time data stream composition and visualisation in the context of energy monitoring. The ultimate goal is to provide end-users with tools that enable them to combine information from various data sources – such as domestic sensors, social media, or public transport – in order to support day-to-day activities and allow them to make informed decisions. As a first step towards exploring this concept, a prototype of a customisable Dashboard system was developed and evaluated in a user study.

The widespread deployment of hardware for sensing various types of data is becoming technologically and economically feasible. As a result, citizens are increasingly producers as well as consumers of real-time data streams – a trend that Paulos et al. term 'citizen science' [7]. The purpose of the Dashboard prototype is to give the user a comprehensive and intuitively accessible overview of data that is relevant to their local household. The study acknowledges that individual users have different preferences with regards to the data that they want to see displayed and the style in which they want it to be presented.

A key contribution of this study lies in the evaluation of the developed Dashboard prototype with actual users, observing their interactions with the system in the environment where they would normally use it. The goal of the study was to determine the persuasive capacity of the Dashboard to allow for different data stream compositions and visualisations. A central question was how participants would make use of customisation aspects of the composable information display and whether it would influence their interactions with the system and their consumption patterns.

2 Related Work

The basic premise of using *Information Visualisation* to display data related to resource consumption is that consumers are lacking information - particularly when it comes to intangible commodities such as electricity. Making consumption data available in an intuitive manner in real-time allows users to better understand the impact of conservation efforts and make informed decisions. Feedback helps to expose consumption which was previously invisible, which is especially the case for domestic energy use. Most commercially available feedback displays rely on an intrinsic rational-economic model, which assumes that people will be motivated by the prospect of saving money [4, 12].

In order for feedback to be effective, it is important to carefully consider what to present and how. Studies have demonstrated that it is easier to persuade users by addressing specific behaviours rather than general ones. Therefore, actionable feedback is required that highlights the necessary steps to reach a desired goal. In the case of energy conservation, this requires systems that are capable of analysing consumption and pointing out potential savings [5, 8, 10].

However, researchers increasingly recognise that the mere availability of information is not sufficient to affect sustained behaviour changes. Nisi et al. observe that many users lose interest in monitoring their energy consumption within weeks and even with the introduction of new visualisations "the novelty effect only [lasts] for less than a week" [6]. Financial incentives can be effective, but many users relapse into old behaviours if the rewards are small in comparison to income and the novelty wears off. A common criticism is that the rational-economic model is not well suited to accurately represent how and why people consume. Strengers illustrates the issue as follows:

> "It is unlikely that most of us, on rising from our slumbers each morning, approach every task 'rationally' by consciously weighing up the costs and benefits of a shower, or ensuring we undertake the most efficient load of laundry." [11]

Strengers elaborates that everyday activities are much more guided by social norms, cultural dynamics, institutional rules, and technological means. If the consumer does not already hold a conviction to conserve energy, then feedback only informs, motivating neither attitudinal change nor action [3, 12, 11].

In order to change behaviour, *Persuasive Technologies* have to consider personal attitudes and interests. Extrinsic forms of motivation can act as triggers to foster intrinsic motivations. Further, it is possible to differentiate between several "stages of readiness, willingness and ableness to change" [3]. He et al. draw upon the stages of behaviour change identified as part of the *Transtheoretical Model* to develop targeted motivational strategies. Because users have different motivations – and these motivations change over time – the authors assert that it is not feasible to develop a 'one-size-fits-all' solution [3, 12].

In their evaluation of *StepGreen.org* – a website designed to encourage energy saving behaviours – Mankoff et al. acknowledge that "no one visualization fits all users and contexts" [4]. The authors plan to address these varying needs by developing a more flexible and adaptive solution. A common approach for achieving this goal is to support end-user customisations, allowing users to personalise their interface. Interaction with the application invokes self-reflection and elicits a sense of freedom, which can increase intrinsic motivation. Further, a personalised interface is a more effective motivator than one that displays general information [3, 4, 13].

There is great potential for *Information Visualisation* to engage people with their resource consumption when it acts as the basis for social interactions. The *Wattsup* application allows users to visualise and share energy consumption data on Facebook. In a study of the application, Foster et al. observed that a socially enabled version was "more enjoyable and more effective than individual monitoring" [2]. The users engaged in banter and competition, which proved to be motivating. A study by Vande Moere et al. that exposed energy consumption on house façades also echoes the beneficial effects of making personal information publicly available, such as peer pressure and healthy competition [2, 12].

This existing research reaffirmed our initial assumptions about the potential value of customisation and social interaction for *Persuasive Technologies*. It encouraged us to specifically explore three concepts:

Customisable Data Sources Do users appreciate the ability to select data sources that are relevant to their personal interests?

Customisable Visualisations Do users gain a greater understanding of the data if they can tailor the visualisation to their needs?

Social Sharing Does the exchange of environmental performance data improve understanding and motivate pro-environmental behaviour?

3 Methodology

The main goal of this study was to develop a Dashboard prototype that could be deployed to users in the real world. Ultimately, the prototype should assist users with their real-world tasks, allowing them to make informed decisions. To maximise adoption, the solution needed to be accessible and user friendly. Therefore, the project was guided by a user-centred design approach.

In accordance with the core principles of user-centred design, the development consisted of several iterations and the results were repeatedly verified with experts and prospective users. The project made use of tools and techniques for rapid development in order to create a succession of incremental prototypes. The main iterations of the development process are summarised in figure 1. A key goal was to employ adequate evaluation methods at each stage of the project.

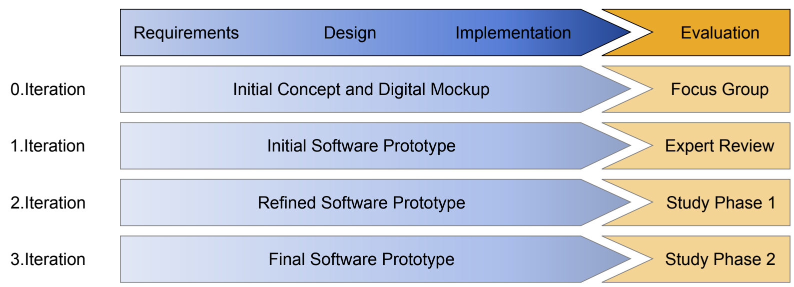

Fig. 1. Iterations during the development.

The project culminated in an exploratory user study, which served to verify assumptions about the role of the Dashboard prototype in a real-world setting. It was carried out as a field trial, spanning two separate phases. Due to the unique characteristics of the prototype, a holistic evaluation of the user experience took place over time in a natural environment rather than a controlled laboratory setting. The study relied on a mix of observational and quasi-experimental methods to estimate the role of the Dashboard prototype with regards to energy monitoring. Quantitative data was collected in the form of empirical usage statistics, tracking various user interactions with the Dashboard system. However, due to the quasi-experimental design, it was essential to supplement this data with qualitative feedback from participants.

4 Design Process

This section describes the activities that informed the major design decisions and shaped the requirements of the Dashboard system. The main concepts of the prototype were fleshed out during the early iterations. In particular, the focus group and the expert review delivered valuable input for the overall design. In the later phases running up to the user study, the development focus shifted towards refining the design, extending the system and addressing usability issues.

4.1 Focus Group

The focus group comprised a total of 8 participants, 2 female and 6 male, aged between 25 and 43 years. They were recruited from the community surrounding the Urban Informatics Research Lab. Some participants were taking part in the overarching research program on domestic energy conservation, meaning that they already had energy monitors installed at home. Furthermore, the group included PhD students in *Human-Computer Interaction (HCI)*. Therefore, the participants were mostly computer savvy and already had experience with energy monitoring. This was deemed to be a favourable constellation, because it was possible to draw from their experience and discuss advanced topics, such as aspects of the user interface. They were also indicative of the early adopters of tools such as the Dashboard prototype, since these individuals are likely to be technically adept and sensitised to the issue of energy conservation.

Over the course of the session, participants worked on different tasks, either collectively or individually. Together, participants collected an extensive selection of different kinds of information that were relevant to them on a regular basis. The broad scope and variety of ideas confirmed our initial concept, because users clearly had a wide range of differing information needs.

Later, individual sketches also demonstrated the great diversity in user expectations. Many of them were quite detailed, featuring innovative ideas for combining and visualising information. The participants often made use of the limited space by displaying different kinds of information within a single visualisation. An example of this was a map that displays traffic congestion and overlays the current weather in the style of a weather map. Energy consumption was commonly presented with a line chart displaying data over a fixed period of time, including one notable exception which adopted a glowing orb metaphor.

4.2 Expert Review

Once an initial working prototype was ready, an expert review was conducted to discover potential problems and ensure that the project was heading in the right direction. A new group of 8 experts was recruited for the evaluation, with about half of them encountering the project for the first time. All of the attendees were colleagues from the Urban Informatics Research Lab. Therefore, the group was mostly comprised of PhD students and academics with experience in HCI. The review took on the shape of a formal usability inspection, where "experts hold a courtroom-style meeting [...] to present the interface and to discuss its merits and weaknesses" [9].

Even though the system was still at an early stage, the core components of the system architecture – the web service and the native tablet application – were already in place, providing all of the basic functionality. The demonstration covered the complete system, including the workflows for authorising services and creating data streams. However, the subsequent usability evaluation was primarily focused on the native tablet application. For this purpose, the experts received a tablet device which had the prototype installed and running, allowing them to configure and customise the Dashboard display.

A number of minor usability flaws were identified and addressed during the next round of development. In general, the experts praised the visualisations that were enabled by the system as well as the implemented sharing functionality. They saw great promise in using the system for social comparison of energy consumption data. The potential of end-user customisation was controversial. In particular, the benefit of combining unrelated information was questioned. Some experts were sceptical whether the presence of certain information, like social media, would motivate users to view the Dashboard display. One participant noted: “If I would like to check my tweets I probably would use the Twitter app rather than a new one.” On the other hand, some experts were optimistic about the idea. Another participant pointed out: “There are some feeds that I know I should be checking in a kind of peripheral vision and then there are some things that I know I check all the time.” He concluded that, “by combining the things I do all the time with the ones that I know I should, but I never do, you kind of get [the best of both].” As a result, the discussion brought attention to the fact that the concept may appeal to some, but not everyone.

5 System Functionality

This section serves as an introduction to the two main components of the Dashboard system developed as part of this research: the web service and the native tablet application. This system architecture is the result of a deliberate design decision to maintain a clear model-view separation. On the one hand, the web service aims to provide a universal data stream brokerage platform. It allows users to manage collections of relevant data streams from heterogeneous services and exposes them through a unified API. On the other hand, the tablet application acts as a client of the web service, using it to discover and query the data streams that drive its visualisations. Its main purpose is to allow users to compose and visualise data.

5.1 Web Service

As a user, it makes sense to start exploring the Dashboard system by visiting the web service and configuring an initial set of data streams. Informally, a stream can be described as a sequence of items. Each item contains multiple attributes that form a self-contained unit of information, such as a reading from an energy monitor or a message on a social network. This highly generic definition allows to model dynamic content from numerous online services.

The core functionality is accessible from an overview page, which is displayed once a user enters the private section of the web service (see figure 2). This page lists all supported services and the associated data sources. The current implementation includes plugins that integrate data from sensors (*Pachube*), government agencies (*Bureau of Meteorology*), social media (*Facebook*, *Foursquare*, *Twitter*), and generic services (*Google*, *RSS*). Users populate their personal collections with streams from data sources relevant to their interests.

Furthermore, the Dashboard web service is a natural place for providing social features. For this purpose, the service incorporates a basic friend system that allows users to interact with trusted individuals. Since data streams are viewed as resources belonging to individual users, their owners can share access to them with their friends.

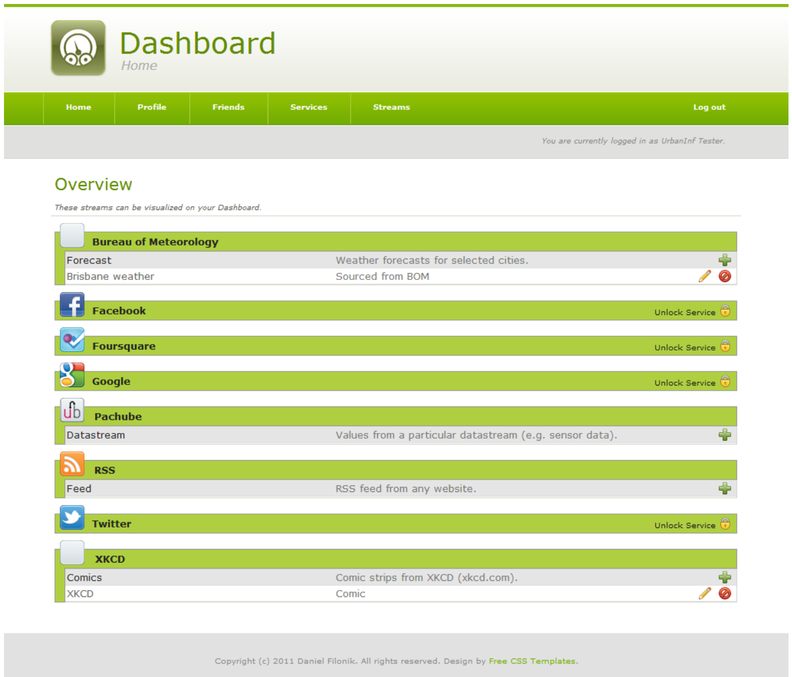

Fig. 2. Overview page showing services and streams.

5.2 Native Application

After configuring data streams on the web service, it makes sense to move on to the native tablet application. The familiar concept of widgets is adopted for representing individual visualisation components. Initially, the display is empty, providing users with a blank canvas on which they can arrange their ideal selection of widgets. This supports the key objective of allowing users to tailor the display to their personal needs and interests. Users can choose from a library of widgets that is bundled with the application, which includes charts (*Line Charts*, *Sparklines*, *Stacked Columns*), maps (*Markers*), images (*Slideshows*), as well as textual (*Notes*, *Messages*, *Articles*) and iconic (*Weather*) representations.

Upon authentication, users are presented with their personal Dashboard display (see figure 3). The 'view'-mode is optimised for information retrieval. By design, the display area is limited to a single screen, showing all personally relevant information at a glance. In 'view'-mode, the widgets do not respond to touches, preventing accidental modification. The only possible action is focusing on a certain widget by performing a double tap gesture. In this state, widgets can receive touch input, allowing for interactive visualisations. In order modify their Dashboard, users enter 'edit'-mode with a long press gesture. Visual cues highlight the transition to a different mode of operation where it is possible to configure, scale, and arrange widgets.

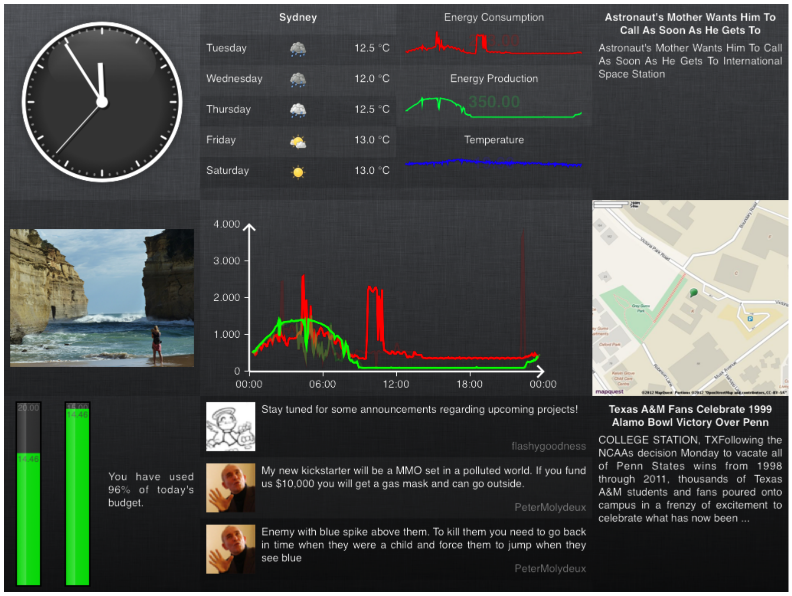

Fig. 3. Main screen showing widgets in 'view'-mode.

6 Evaluation

During March 2012 a refined prototype was deployed to five new subject-matter experts for a period of three weeks. Participants ranged in age from 27 to 43 with differing technical backgrounds, including HCI and interaction design. Three of the participants were regular *iPad* users. Taking the prototype out of the laboratory and into the homes of participants was the natural next step following our on-site expert review. After the initial setup of the Dashboard with the researcher present providing instructions, the expert users were asked to customise their Dashboard display to suit their needs. During this deployment the directive was to make use of the Dashboard and to identify any issues. Ad hoc feedback was gathered via email correspondence. Structured feedback was gathered using interviews, with each participant interviewed prior to using the Dashboard, and at the end of the three week trial. Using these methods, participants were able to describe in detail the aspects of their interactions with the device, their observations of usage patterns and adjustments to their routines. Participants critiqued the usability of the prototype in post-interviews, and also reflected upon their usage patterns and overall impression of the Dashboard.

In May 2012 a larger five week study was undertaken, deploying the final prototype to members of the local community. The most serious usability issues were addressed to make the system more intuitive for participants. The widget selection was increased and existing widgets were improved using participant feedback. Overall, 13 participants from 12 different homes were sourced as part of a larger program of research into energy conservation, each having their own *iPad*. These participants already had a *CurrentCost Envi-R* energy monitor installed in their homes, and basic demographic data had been recorded. Again, participants were individually interviewed twice, at the beginning and conclusion of study phase 2. Numerous individual interview questions teased out the function of the Dashboard for each participant. Initial questions sought high face validity, e.g., "what impact, if any, do you think the Dashboard had." Later questions targeted the impact of customisable information visualisation and end user customisation. Additionally, at the conclusion of this deployment, the most socially linked participants were included in a two-hour phase 2 focus group. This second focus group further investigated the persuasive elements of the social sharing components of the Dashboard.

The usability evaluation clearly showed that the prototype, while providing a level of feedback that the users found novel, needed more refinement. The issues revolved around configuration, interface presentation, and requisite diversity of widgets to satisfy their individual requirements. These shortcomings will be addressed in future iterations.

6.1 Social Ties and Voyeurism

In the phase 2 focus group, it became clear that while participants showed preference for different Dashboard widgets, the overriding element that helped to persuade some to remain engaged was the ability to share and compare energy consumption. This theme featured prominently throughout the phase 2 focus group and is exemplified by the following statement by Ronaldo (names have been replaced throughout), "I did notice an uptake in using the Dashboard once I had Fernando and Paolo on there as well. Once I was able to overlay my consumption with theirs, because thats the only app where I can do that, I kind of checked on that more often."

Another theme that emerged was the feeling of *voyeurism* that Fernando commented upon, jokingly stating that he felt the desire to "obscure" his energy consumption, knowing that Ronaldo was watching. Fernando then commented on Paolo's energy consumption stating "Paolo you can tell when [housemate 1 and 2] get home, at 6pm onwards, there's a spike." Zinedine stated "maybe you could see OK, there's a party going on in Fernando's house or something and then follow up." This theme supports previous research publicly exposing energy consumption [12], and offers a persuasive method for engaging participants in the future. The underlying message here was one of comparison with those participants who shared social ties [1], e.g., Ronaldo benchmarking his already low energy use with Fernando and Paolo. The ability to compare or play energy voyeur represent real avenues for motivating energy conservation.

Speaking on this topic Ronaldo related his own experience; the emergence of an informal group of three friends involved in curbing energy use when he became interested in lowering his energy consumption. The group achieved excellent results with all members lowering their energy consumption, eventually installing solar panels and hot water, trading knowledge and appliance usage patterns through collaborative documents. They reached a maintenance mode after a period of months [3], where their collective learning plateaued and members, having made lifestyle concessions to consume less energy felt that they had reached their goals. The group established a new norm for their energy consumption and behaviours through a learning process facilitated by engaging with socially linked individuals. Ronaldo's knowledge sharing conducted in the phase 2 focus group was enabled by the Dashboard energy widget. The ability to compare real-time energy consumption data with friends over a period of time is a clear pathway for other persuasive tools [2, 11].

6.2 Data Stream Composition

The notion of having a customisable Dashboard, and view multiple streams of information in one interface was regarded positively by the participants. Each participant adapted their Dashboard to their own interests, with Fernando displaying the densest Dashboard with RSS feeds (for daily deals and discounts), social media, local news, weather, and multiple energy widgets (both for consumption and photovoltaic production). The aspect of combining widgets to deduce useful information was exemplified by participants with solar panels. Conscious of the return on their sustainable energy investment, these participants re-purposed the weather widget to both predict and deduce the reasons for differing levels of energy production displayed by the energy widget.

Fernando and the other participants agreed that they were seeing their energy consumption frequently by using the Dashboard, but were often just monitoring the pattern displayed on the energy graph. The experience of the participants meant that they were often displaying a maintenance behaviour, noting that "nothing was wrong" and then moving on. Echoing this comment, another participant mentioned in their final interview that a simple red light/green light would be helpful for providing feedback on "excessive" energy use. Future widgets should cater to this information seeking behaviour providing simple, at times ambient visual cues to facilitate maintenance behaviours for participants.

Participants viewed displaying multiple configurable information sources on a single display as useful, though in certain cases they were unable to articulate how they would use such a tool on a day-to-day basis. This may represent a source of bias in their responses or familiarity with the interviewer. As this study is positioned as exploratory and experimental the day-to-day use of the Dashboard was not applied as a metric of success or failure.

6.3 Intrinsic Motivation

When asked what their intent was when viewing the Dashboard, most participants stated that they went to look at the energy consumption widgets. This behaviour was especially prevalent on those with solar panels, which appear to be an indicator of energy consumption awareness. The desire to derive maximum value from previously unmonitored equipment was often the reasoning offered by participants. The budget widget with a configurable total was Zinedine's favourite. The widget provides a column that fills as a target is reached, and was added based upon feedback in phase one on goal setting. Zinedine had put it to use as a way of tracking solar production commenting, "I'm trying to generate 10 kWh per day, so it just gives me a percentage of how much I've done". The line of thought extended with Zinedine introducing the concept of cross-widget scripting, where if the budget target was reached the power might be shut off for his home or the lights might dim at 50%, acting as an alarm. This presents an interesting next step for this research considering widget mash-ups designed by users to suit their desires. In line with this suggestion Zinedine stated that he would like to be seen as an author of content when another friend adopted one of his shared widgets on their Dashboard. This form of recognition was ideal for Zinedine as long as he was able to see how many people were using it. Applying this notion of participants deriving status from the creation and use of customised widgets by others is another avenue for future research.

Participants were not readily able to assess a change in energy consumption after having used the Dashboard. This was often related to lifestyle norms [11], or for more experienced participants a sense that they were already informed about their energy consumption and had minimised it. For experienced participants the energy widgets did not represent value until the social comparison and budget features were provided. As was described previously, these helped experienced participants remain engaged, perform maintenance behaviours, benchmark their consumption, and caused serendipitous social interaction.

7 Conclusion

Through our exploratory study, we gained a better understanding of the opportunities and challenges of deploying a customisable Dashboard display in a domestic environment. We observed strong indicators that some of our assumptions materialised and provided real benefits for energy monitoring. With regard to customisation, most users appreciated the ability to select visualisations and many of them desired a greater widget selection with deeper data analysis functionality. In particular, users were enthusiastic about compositions of widgets that allowed the to investigate relationships between the data, such as the correlation between weather and energy consumption.

The most promising dynamics with regard to energy conservation arose in the socially enabled condition. Participants that shared their energy consumption with others were likely to exchange expertise and troubleshoot problems. Furthermore, we observed the emergence of energy-voyeurism, a form of social energy monitoring where users – driven by their own curiosity – compared and analysed the energy consumption of others.

In concluding this work, it should be noted that of recurring interest to this work is the need for more research into the inherent interest of individuals in their energy consumption behaviour. A clear avenue for future research is in developing a toolset for assessing the likelihood for an individual of adopting or rejecting energy conserving behaviours. This assessment should also include the relative perceived impact upon lifestyle.

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