The Gorilla in the Library: lessons in using ICT to engage building users in energy reduction

Dr Richard Bull	Dr Graeme Stuart	Dave Everitt
De Montfort University	De Montfort University	De Montfort University
The Gateway	The Gateway	The Gateway
Leicester, LE1 9BH	Leicester, LE1 9BH	Leicester, LE1 9BH
+44 (0)116 207 8063	+44(0) 257 7964	(+44) 0116 250 6146
rbull@dmu.ac.uk	gstuart@dmu.ac.uk	deveritt@innotts.co.uk

1. Introduction

This paper is concerned with the role of the digital economy as an enabler of behaviour change in the built environment. The Greenview research project at De Montfort University (DMU), funded by JISC's Greening ICT fund[1], has undertaken innovative work to explore novel and interesting ways to engage building users in energy reduction. Findings are presented around both the methodological challenges of capturing and presenting live electrical data for iPhone applications and the wider opportunities and barriers to ICT enabled behaviour change. From a technical perspective Greenview has shown the need to conduct detailed and thorough technical work to ensure the visualisations correlate to actual building performance and from the behaviour change perspective both Greenview and its predecessor (DUALL[2]) have explored moving beyond quantitative approaches to presenting information on energy and sustainability that is fun, creative and [hopefully] engaging. Finally, it is clear that without senior commitment and sincere staff engagement and collaboration mere information provision in the form of dashboards are impotent.

2. Background & Context

Recent research into energy wasted through lights left on in unoccupied non-domestic buildings at night and at weekends was found to be as high as 30% of total unoccupied use (Brown, Wright et al. 2010). Increasing research is being done into re-connecting people to energy in their homes through the use of novel display screens and smart-meter systems that may show the price, unit-cost or CO_2 of the electricity used through either a live feed or half-hourly metering (Hargreaves 2010; Meyers, Williams et al. 2010). Whilst these have demonstrated potential in reducing consumption by up 10-15% (Burgess and Nye 2008) these interventions are based on an 'information-deficit' model – if 'they' have the right information 'they' will change behaviour, as well as centering on numerical representations of data to induce behaviour change.

There has also been a significant rise in the use of digital economy tools such as smartphones in energy related behaviour change initiatives. The modern smart-phone is web-enabled, has access to social media, a camera (often with video capability), global positioning systems (GPS), able to send text messages (and even make calls!). Further to this is the plethora of bespoke applications ('apps') designed to run on smartphones, especially Apple iPhones and Android phones. Various research institutes are designing apps for phones that will enable them to receive energy data on buildings (Lehrer and Vasudev 2010; Weiss, Loock et al. 2010). With regards to energy and the built environment, research has been done in the Institute of Pervasive Computing in Zurich (Lehrer and Vasudev 2010) to explore the technical side of using mobile phones as consumption feedback devices and increase energy awareness. Less research has been done in the workplace and how to effectively engage employees in energy reduction methods, and the literature shows that the majority of smartphone and ICT initiatives still rely on numerical representations of the energy data.

Greenview built on the successful DUALL project, funded by JISC. DUALL utilised a socio-technical solution to the design of a simple web based information-feedback tool that could report electrical consumption of ICT equipment back to users. Progress was positive inasmuch as a small group of building users were engaged and a simple dashboard using Yahoo widgets developed. Greenview aimed to refine the ICT tool further into a more sophisticated smart phone application that would connect staff and students in DMU to the energy consumption of their buildings. We succeeded in developing an iPhone 'app' which was launched in March 2012. The app visualises energy use in buildings on the DMU campus through creating a narrative of buildings as habitats for endangered species, with a view to moving away from numerical ways of data presentation and testing a fun and engaging way to look at how we can look after our environment. The app provided real-time data through meter readings provided on a half-hourly basis, and with the inclusion of graphical data options, appeals to the range of preferences individuals have for viewing and interpreting data.

3. The Research Challenge

3.1 Meaningful Data

The first challenge was to ensure the data was presented in a meaningful and accurate way providing the user with useful and timely feedback. The key question to resolve was how to quantify the energy performance of each building and present meaningful data to the building users. All of DMU's buildings have half-hourly metering for gas, electricity and water. Data are relayed via a low-power radio network to a central receiver, and are then uploaded to a MySQL database server. The aim was to reduce the complexity of building energy data to a simple low/neutral/high category. It had been agreed by the team to present these states as happy, normal and sad respectively in the final app and to explore what effect these 'emotions' may have on the building user. The approach needed to be directly calculable from 'live' energy

---

consumption data and buildings must switch between being happy and sad over time. For this, a simple energy consumption model was developed whereby each building has its own dynamic definition of 'normal' – that is, comparing each building with its own previous consumption. This is preferable because it provides positive feedback if improvement is made and negative feedback when performance deteriorates.

'Normality' for each building was determined from the latest 12 months of consumption. By using a rolling 12-month window the data used to generate the 'normal' model changes over time. As new data are collected, older data are discarded and the definition of normality changes for each building. This means that as the pattern of consumption changes the model will also change and the baseline model is always up to date. The model is based on a weekly pattern because the most significant predictor of electricity consumption in the Greenview buildings is 'time of week'. Each building has a unique signature that can be extracted and analysed. For each of the 336 half-hourly periods in a week, an analysis of the distribution of consumption levels was used to calculate the 'normal' range of consumption values in that period. Figure 1 shows a weekly period of consumption with each week overlaid on top of each other to gain a picture of 'normal'. It is clear that the signatures for most individual weeks are similar but each week of data is unique. Also plotted is the median (50th percentile) for each of the 336 half hourly periods.

Figure 1: A weekly period of consumption with 'normal' mapped)
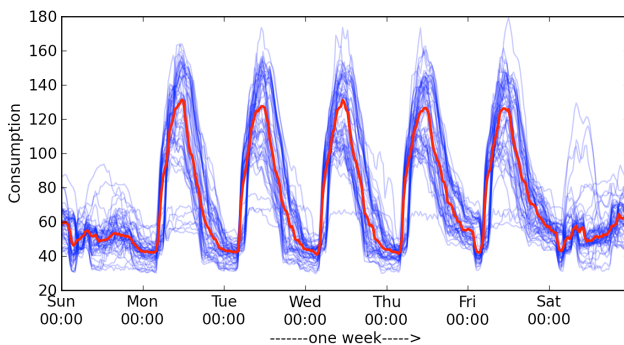
The 25th and 75th percentiles of each period were used to establish the inter-quartile range as the 'normal' range of consumption. By comparing the latest consumption values with the model (in the appropriate time period) it is always possible to categorise a data point accurately. Anything above the inter-quartile range was considered 'high' or 'bad', anything below this was considered 'low' or 'good'. This approach had many advantages, notably, no matter what time of day or what day of week the assessment is made, the model adjusts accordingly and gives a sensible threshold. The consumption pattern only needs a small, persistent nudge to change the balance and provide the required feedback.

3.2 Creative visualization

Greenview's aim was to create a fun and engaging way of communicating energy efficiency as a layer above the commonly seen quantitative approaches attributing numeric values to energy consumption as money, carbon or kilowatt hour – although these were available. Our team designed three animations each for five DMU buildings from the 15 on campus (Fig 2), each 'inhabited' by an endangered species (Fig 3) to give the building a sense of personality, and to hint at a connection between energy use and its impact on the natural world. The final five were chosen because they were viewed as dominant and easily recognizable campus buildings (time and financial constraints also limited the number of animations).

Figure 2:The five university buildings characterised as 3D models

For each building, three animations were created to illustrate states of energy consumption: 'happy' if lower than the defined 'normal' band, 'neutral' if within normal range and 'sad' if higher than normal. The animated animals reflected these states by appearing happy, neutral or sad (e.g. 'sad' penguins appeared lonely, with dead fish scattered around, 'sad' skies appeared darker with aircraft contrails, and some poorly-performing buildings exuded smoke).

Figure 3: The five endangered species chosen to represent the buildings
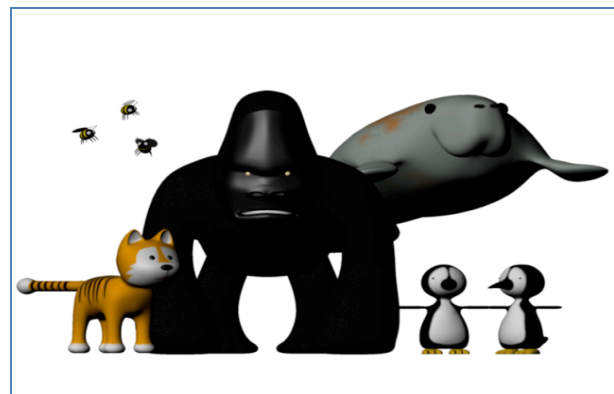
Before construction, a visual storyboard and schematic diagram was created to clarify processes within the proposed app. Although these were changed and some functionality omitted, this structure divided 'back-end' processes from those required in the user interface and detailed the links between them. The structure had four tiers of functionality, two server-side and two within the app itself, which was preceded by a rough pilot to test the readings (see http://greenview.ecoconsulting.co.uk/). Although developed primarily for Apple's iPhone and iPad (an Android version proved impossible due to Android's patchy video support) the project used PhoneGap (rather than Apple's Objective-C) to wrap web technologies (HTML5, CSS3 and Javascript) in an iOS 'container' using its 'web view'—an instance of the system's web browser, and acceptable on Apple's App Store. Frankly, this played to the team's strengths and also enabled a higher degree of portability (the app can run in a standard web browser, although this is not currently viewable). While slower than a native app this was not an issue; once the app is downloaded with all 15 videos a simple Javascript Ajax call updated the data. The overall result enabled users to check the current state of a building at any time of day, and immediately see whether its energy use was average, below or above its usual parameters. The aim was to evoke an instant visual and emotional appeal to stimulate public engagement with the app, an approach which animated the raw

statistics and enabled immediate comprehension of a building's performance. To address the issue of the app appearing over-simplified, further information was made available in the form of detailed graphs covering longer periods, and a 'top trumps' style card containing building data.

4. Discussion

To evaluate the Greenview app a focus group was organized and facilitated by a neutral Chartered Occupational Psychologist from Arup, with assistance from DMU. In total, 11 participants attended the session. This included seven staff and students from DMU, including environmental champions (staff from across the faculties and buildings) and a Masters student. Respondents in the focus group evaluated and commented on the Greenview app from three perspectives: usability, design and content and functionality.

4.1 Usability

Usability is a key feature of apps now and it was clear from the group that whilst there was an initial positive first impression of the app, the animations needed a clearer explanation of what they were representing. Participants felt that the graphs ideally need to be easier to interpret, and to clearly show that the information presented is 'live'. Whilst the app had 'novelty' value several participants commented on the need for the app to be available in either a web-based or PC format, to increase the accessibility to a wider range of stakeholders. Finally, participants felt that there needed to be more contextual information provided within the app to explain the possible reasons why energy usage levels are showing as high/low.

4.2 Design and Content

Providing comparative data emerged as a key recommendation. This is interesting as the core model underpinning the app was meaningful *historical* comparison for each building, people wanted to compare and compete with other buildings. Users were also keen to see the app be able to send 'alert' messages to users, which would prompt the user to go into the app, would increase engagement. In addition, if users were able to select which buildings they want to receive alerts about (as above), the alerts could be tailored to the specific buildings selected, and this would further increase perceived relevance to the user. Participants were divided on whether the use of the endangered species was the most effective way to communicate the importance of the energy use messages to users. Some felt the animals may be perceived as too childish and would perhaps only appeal to children or younger people. But the use of emotion and facial expression was seen as very powerful and something which should be enhanced within the app to increase the power of energy use messages.

4.3 Functionality

The need for more animation and interactive functionality was reiterated here too; being able to interact with the data, graphs and animated features would promote engagement and understanding of the data presented. It was also felt that the graphs could benefit from showing data in smaller time increments, such that users could opt to view specific times of energy use (e.g. during a particular day), to be able to pin-point potential reasons for 'spikes' in the data. Interestingly, having been keen to move away from numerical representations of the data users were keen to see feedback in units that users would be able to relate to (such as monetary value, or the number of books that could be bought for the library, for example).

5. Conclusion

This paper was chiefly concerned with the role of the digital economy as an enabler of behaviour change with specific reference to reducing energy in buildings. Greenview has successfully contributed to the on-going debate through both devising a method for providing meaningful energy data that learns and reacts to individual behaviour, and creating a working app that presents energy data in a unique way. However, it is essential we know the best way to engage and motivate people and that we have a realistic understanding of the benefits and limitations of such approaches. For this, evaluation is key and herein lays the difficulty – attributing behaviour change to such an intervention like Greenview is problematic and for this ongoing studies including follow-up interviews of the users are required (and planned). Nevertheless, Greenview explored moving beyond linear quantitative approaches to presenting information on energy and sustainability that is fun, creative and engaging. And yet, users still found numerical and easily understood representations of energy useful. We also have seen over the two projects that without senior commitment and sincere staff engagement and collaboration mere information provision in the form of dashboards is impotent. Overall the participants found the tool user friendly, fun and visually attractive, however, the need for it be more intuitive and interactive, with the provision of guidance for users to help them behave differently with regard to energy use, were key recommendations. Furthermore we hope to inspire more creative and ambitious use of the digital economy in order to appeal to a wider audience than the usual suspects already converted to environmental issues and energy conservation.

References

Brown, N., A. J. Wright, et al. (2010). "Longitudinal analysis of energy metering data from non-domestic buildings." *Building Research & Information* **38**(1): 80 - 91.

Burgess, J. and M. Nye (2008). "Re-materialising energy use through transparent monitoring systems." *Energy Policy* **36**: 4454-4459.

Hargreaves, T. (2010). "The Visible Energy Trial." *Tyndall Working Paper* **141**(February).

Lehrer, D. and J. Vasudev (2010). Visualizing Information to Improve Building Performance: A study of expert users. ACEEE Summer Study on Energy Efficiency in Buildings.

Meyers, R., E. Williams, et al. (2010). "Scoping the potential of monitoring and control technologies to reduce energy use in homes." *Energy and Buildings* **42**: 563-569.

Weiss, M., C. Loock, et al. (2010). Evaluating Mobile Phones as Energy Consumption Devices. Proceedings of Mobiquitous 2010 (7th International ICST Conference on Mobile and Ubiquitous Systems.

General Terms

Algorithms, Measurement, Design, Economics, Human Factors,

Keywords

Energy visualization, public engagement, behaviour change,