Greenview: The Gorilla in the Library
Smart Sensing and Behaviour Change

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Abstract – *This paper provides a description and analysis of the Greenview project, an experiment in smart sensing leading to energy consumption behaviour change in building users. Greenview was an innovative app built on the back of the successful DUALL project (funded by JISC). Where DUALL created a simple web-based information-feedback tool that could report electrical consumption in specific university buildings back to users via a simple dashboard using Yahoo widgets; Greenview refined the ICT tool further into a sophisticated smart phone application which could connect staff and students in De Montfort University (DMU) to monitor the relative energy consumptions of their buildings.*

The developed iPhone 'app' visualised comparative energy use on the DMU campus through a narrative of improving or declining habitats for endangered species, represented by animated cartoon characters living as virtual mascots in each university building. Based on the emotive nature of the 'Tamagochi' concept, the app tested an engaging way to encourage care for the environment. When consumption levels exceeded those on the same day of the previous year, the visible well being of species would change. The app also provided real-time data through meter readings provided on a half-hourly basis, allowing the inclusion of graphical data options, appealing both to emotional identification with the building mascot and to the range of preferences individuals have for viewing and interpreting data.

I. INTRODUCTION

"When citizens become involved in working out a mutually acceptable solution to a project or problem that affects their community and their personal lives, they mature into responsible democratic citizens and reaffirm democracy. One way of describing this phenomenon is to use the term social learning." [1]

The assertion by Shirky [2] is made in the context of energy, the built environment and the challenge of behaviour change. Webler *et al* [Ibid] affirm the potential that citizen engagement and participation may have on behaviour change in the form of social learning. With the introduction of the Climate Change Act in 2008 the need for action became clear. The UK was first to pass legally binding and ambitious targets for greenhouse gas emissions, specifically a reduction of at least 80% by 2050. The built environment has an important role to play if the UK is to meet this target, with almost 20% of the UK's energy consumption and CO_2 emissions arising from non-domestic buildings. Energy in buildings then is a key strategic issue, not just for universities but for any large organisation. Both in terms of financial spend and environmental impact, buildings have a significant carbon footprint which, alongside increasing legislative drivers, creates a compelling business case to reduce energy consumption in buildings.

To date the most common way to join ICT and behaviour change has been by exploring novel ways to provide information. For example, in the field of domestic energy use, and to lesser extent the workplace, research has engaged with ways to re-connect people to energy through the use of systems that show the price, unit-cost or CO_2-cost through a live feed or half-hourly metering. Visualising energy has emerged over the last few years as a key research area for environmental scientists ([3], [4]) and has shown potential in reducing consumption by up 10-15% [5]. These interventions are based on an ‘information-deficit’ model – if ‘they’ (i.e. the users) have the right information ‘they’ will change behaviour. The prevailing tone of this literature and research is paternalistic, with someone-the ‘expert’ (or management or government), influencing other people (residents/staff/non-experts) to stop behaving one way and start behaving in another. Underpinning these approaches are often a range of environmental psychology models that attempt to unpick an individual’s attitudes and behaviour in relation to energy [6]. This ‘ABC’ approach to behaviour change has been criticised by academics [7] who argue that behaviour is more complex and the result of deeply ingrained social infrastructures, values and institutional and organisational barriers that undermine or limit the impact an individual may have.

At the time of the project’s inception, the Institute of Creative technologies (IOCT) at DMU had already developed a number of other projects, which used social media, augmented reality, GPS technology, and wiki or crowd-sourcing knowledge approaches to engage with the public in what we would term “hybrid” city environments. This ability to reach out and map layers of information onto the cityscape formed the foundation to this project. Work on iphone and Android platforms helped to add an interface combining interpretation of energy monitoring detail with immediate graphic representations. The intention was to allow micro-management of energy use, the rendering in a transparent manner of use patterns in public and corporate buildings, incorporating motivation through serious game strategies to build group and collective engagement in the problematic.

The Greenview project built on the successful DUALL project (funded by phase 1 of JISC’s Greening ICT call). 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. DUALL - the ‘deliberative user approach to the living lab’ (DUALL) tried to recognise the complexity of user perceptions and understandings [8] the importance of combining a bottom-up and top-down approach in order to minimise mixed messages [9] and the value of public engagement ([5], [10]).

Greenview aimed to refine the ICT tool further into a more sophisticated smart phone application that would connect staff and students in De Montfort University (DMU) to the energy consumption of their buildings. We succeeded in developing an iPhone ‘app’ which was launched in March 2012. The app visualised energy use in buildings on the DMU campus. It presented the buildings as living habitats for endangered species mascots, providing an engaging way to 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.

Greenview utilised the expertise of two distinct but complimentary DMU research groups, namely the IESD and the Institute of Creative Technologies: the IESD was a leading research institute conducting innovative and groundbreaking research into renewable energy, sustainable development and public engagement. Current research was driven by the UK's commitments to reduce greenhouse gas emissions, increase the use of new and renewable energy technology and provide a high-quality, comfortable, safe and efficient built environment.

Whilst the DUALL project aimed to uncover whether involvement in the design of ICT-based user applications can affect behaviour change, Greenview extended the reach of DUALL and specifically aimed to transcend the traditional form of web-based representations of energy into something more dynamic and participative, which enables staff and students to not just see the energy performance of every building, but to map issues and recommendations pertaining to energy consumption onto a central website. The data was further interpreted visually onto mobile platforms, as outlined above, using visualised forms of readily digestible statistical data.

II. THE RESEARCH CHALLENGE

The specific aims and objectives were as follows, and directly related to key themes drawn from the range of research covered by the JISC Greening ICT community.

1. Creating Meaningful Data

The first challenge was to ensure the data was presented in a meaningful and accurate way. A tool was needed to provide 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 had 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 in the mascot avatars as *happy, normal and sad* respectively in the final app. The approach needed to be directly calculable from 'live' energy consumption data and buildings would 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 on the same day of the preceding year. This had many advantages, primarily because it provided positive feedback if improvement was made and negative feedback when performance deteriorated.

Normality for each building was determined as a function of 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 was collected, older data was discarded and the definition of normality changed for each building. This meant that as the pattern of consumption changed the model also changed and that the baseline model was always up to date. The model itself was based on the weekly pattern because the most significant predictor of electricity consumption in the Greenview buildings was 'time of week'. The daily and weekly occupancy cycles related to building opening times and weekends determining when the building energy systems were in use. Each building had a unique signature that could 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 using a weekly period of consumption with each week overlaid on top of each other to gain a picture of 'normal'. It became clear that the signatures for most individual weeks are similar but each week of data is unique. Also plotted in is the median (50th percentile) for each of the 336 half hourly periods.

2. Data modelling and analysis

We wanted the feedback to reduce the complexity of building energy data to a simple low/neutral/high category. It had been agreed by the team that we would present these states as happy, normal and sad respectively in the final app. 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' – we would be comparing each building with its own previous consumption. This has many advantages, primarily because it provides positive feedback if improvement is made and negative feedback when performance deteriorates.

3. Design of the App

Greenview's primary aim was to explore a funny and creative way of communicating energy efficiency that didn't just show numbers – although these were available. Our team designed bespoke animations of five DMU buildings (Fig. 1) 'Inhabited' by endangered species (Fig. 2).

For each of the five chosen buildings, a separate animation was created to illustrate the three possible states (Fig. 4) of energy consumption; 'happy' if lower than the defined 'normal' band, 'neutral' if within the normal range and 'sad' if higher than normal. The same 3 states also drive a more detailed graph, available within the app for those requiring further information. To add to the playfulness of the interface, the same three states also determined which 'top trumps' card was shown—these contained further static information about each building, but are designed to appear more or less 'worn' according to each of the three states.

Figure 1: The five university buildings characterised as 3D models.(Design: David Everitt)

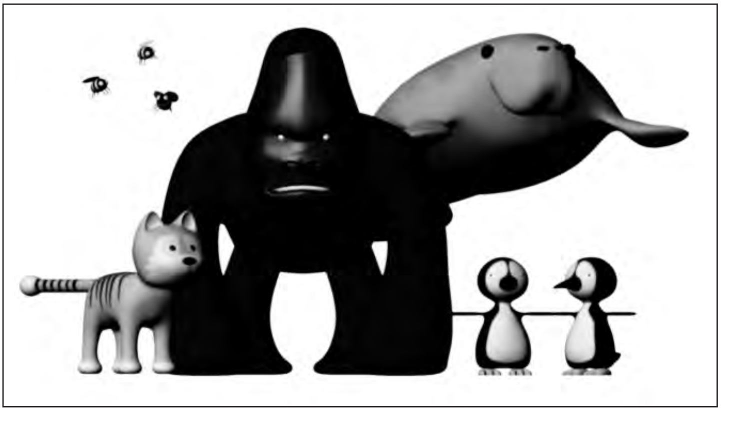

Figure 2: The five endangered species chosen to represent the buildings. (Design: David Everitt)

Before construction, a visual storyboard outline and UML-like (Fig 7) diagram was created to clarify the processes within the proposed app and—although the storyboard was changed and some diagrammed functionality was omitted—this provided the basic structure, dividing 'back-end' processes from those required in the user interface and detailing the necessary links between them. The basic structure had four distinct tiers of functionality, two of which reside on web servers, and two within the app itself:

1. The web service generating the raw data (web server 1);
2. 'Middleware' that processes the raw data for the app to use and is called by a Linux 'cron' (timed) script at regular 30-minute intervals (web server 2);

3. Javascript to read in the data and generate both detailed graphs and the three basic states—this does most of the dynamic work necessary for the app's interface to respond to each of the three states (app);
4. The presentation layer that appears to the user (app).

The app was created after some initial functional tests to rough out the basic Javascript code and check the resulting readings (http://greenview.ecoconsulting.co.uk/). Although developed primarily for Apple's iPhone and iPad (and the iOS operating system that these share), with a possible Android version in mind, it was decided that using Apple's Objective-C code would be less productive than using web technologies (HTML5, CSS3 and Javascript), so the finished app was 'wrapped' in a 'native' iOS container using PhoneGap, one of the two most popular tools for this process. The result is a native app that utilises the platform's 'web view'—an instance of the system's web browser. While slower than a native app this was not an issue as—once downloaded with all 15 videos (5 buildings x 3 states)—a simple Javascript Ajax call pulls in the latest data. A further advantage of this method is that Greenview can also be made to run in a desktop/laptop browser.

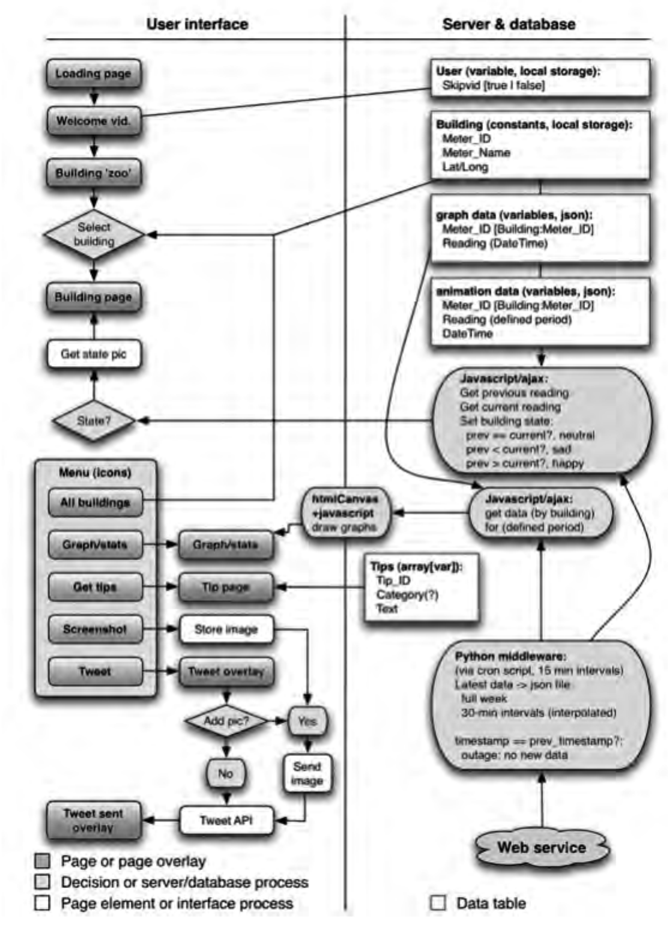

Figure 3: UML-like diagram of the proposed app.

However, it was later discovered that Android's handling of video files is inconsistent and buggy, and this—even with informal input from a specialist—made an Android version using the animation videos so difficult that the option was abandoned. The development process of the main app was captured using the version control software GIT and finally uploaded to a public repository on the GitHub social coding service, although this was not enforced throughout, and 3-4 separate 'frozen' versions of the app still exist outside version control.

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 is average, below or above its usual parameters. The three states for each building pervade the entire app, and are immediately visible on the main screen. Video stills for the three states of one building are shown below (Fig 4). Much care was taken over the animations to ensure that the 'personality' of each building and associated animal had an instant visual and emotional appeal, and this has been a major factor in stimulating public engagement with the app.

Figure 4: Video stills from each of the three states for one building.

Since the launch, the processed data was continuously available to the app and, although the web service delivering the *raw data* is occasionally offline (outages are monitored using the same script that pulls in the data: the longest period was 14hrs), the code allows for the app to be used at any time with the latest available data—the middleware will pull in the latest data when it becomes available. A small code snippet using HTML5's local storage also ensures that the currently selected building is 'remembered' on the user's device until another is chosen.

III. EVALUATION

To evaluate the user-opinions on the Greenview app it was decided to organise a focus group due to both methodological choices and practical constraints. Because of time constraints this was viewed as a better use of time than trying to organise multiple interviews and then subsequent transcription and analysis. But, methodologically, focus groups are seen by many as an extension of the interviewing process ([11], [12]), Focus Groups allow greater exploration of why people feel the way they do about a particular issue. Moreover, participants have greater control to express their viewpoint. Finally, they provide an interesting opportunity to witness how "individuals collectively make sense of a phenomenon and construct meanings around it" [11].

The Focus Group was designed and facilitated by a neutral Chartered Occupational Psychologist from Arup, with assistance from DMU. This approach would ensure a 'neutral' presence and lead, encouraging maximum engagement and output from participants, with co-facilitation by a member of the University's Institute of Energy and Sustainable Development and Principal Investigator of Greenview.

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. Four members of Leicester City Council were also invited, as one of the aims of the focus group was to learn lessons from Greenview that could feed into recommendations for our participation in the SMARTSPACES project[1]. It was considered that the range of stakeholders in attendance provided a sufficiently representative sample of participants to provide a valid review of the Greenview app and input SMARTSPACES.

Following the initial welcome activities and energiser activity, participants were presented with an overview of the Greenview App, including background and context for its development, and an overview of key features. Participants were also provided with a 'walk-through' of the app using two ipads and an iphone. This enabled all participants to engage and interact with the app and ensured that all participants had a full and shared understanding of the app's features and functions. Participants were then provided with an overview of key behavioural influencing factors, gained from psychological research into the area of 'Green behaviours', to enable participants to begin to consider how the Greenview app currently might influence the behaviour of users. Various key themes for exploration, together with key 'prompt' questions, were then presented to the participants for their consideration. The key themes and prompt questions are provided below:

1. **Usability:** How easy is it to use? Is the information easy to understand? How convenient is it to use? What are the barriers to use (if any)?
2. **Design:** What design elements work well/not so well? How could the design be improved (style, layout, format)?
3. **Functionality:** Does the app provide all that it should do in terms of functions? What can or can't it do? What else should/could it do?

[1] Smartspaces is an EU CiP project (EU/297273) enabling public authorities across Europe to improve the management of energy in their buildings by exploiting ICT. DMU is responsible for the evaluation of the project alongside being a 'pilot site' with Leicester City Council. This means designing an implementing an energy visualisation tool across a range of public buildings in the local authority and the university. For further details, see: http://www.smartspaces.eu/index.php?id=629

4. **Content:** How could the content be improved? What other information should the app provide? Does the content/information help prompt you to save energy? Does it help you understand HOW to save energy? What other information/feedback should be included?
5. **Attitudes:** How do you view the app? What are your perceptions? Does the current app help you to change your views and behaviours relating to energy saving? Does it tap into your feelings and emotions? How could this be improved? Would you encourage others to use it?
6. **Other:** What else can we capture about what the app? What other positive things? What else do we need to consider in improving the app? Are people changing any aspect of their behaviour? Are people uploading information and engaging with the energy management team as a result of the tool?

In order to ensure that all participants were given the opportunity to 'voice' their ideas, they were all given post-it notes to capture personal thoughts and ideas throughout the presentation of the key themes and prompt questions, and were given a short period of time (15 minutes) to capture their individual thoughts and 'map' these onto themed flip-chart sheets provided around the room. Following a brief facilitated exploration of the ideas posted on the walls, the participants were then asked to work in three mixed stakeholder groups (two groups of four and one group of three), to further develop their ideas and to capture key ideas and develop recommendations for improvement for the app. The outputs and recommendations are provided below.

Respondents in the focus group evaluated and commented on the Greenview app from three perspectives: usability, design and content and functionality.

1. Usability

Through the discussions, the need to maximise engagement and making the app as easy as possible to use emerged as key considerations. Participants felt that in order to ensure users engage with and continue to be interested in the app and its content, the animations need a clearer explanation and to be easier to interpret. Making the app more interactive, for example through making the animals interactive, would also help maintain interest and engagement. Participants felt that the graphs ideally need to be easier to interpret, and to clearly show that the information presented is 'live'. The data needs to be intuitive and self-explanatory if such information were to be displayed on a public display screen. 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. In addition, the need to consider what would prompt staff to view the information was mentioned.

Having the data available through a link on the DMU staff portal, providing prompts when starting up computers, or having the data as a screen saver/wallpaper were all seen as potential ways to make the data more easily and readily accessible to staff. Finally, participants felt that there needed to be more contextual information provided within the app (and also provided on display screens if used) to explain the possible reasons why energy usage levels are showing as high/low. This rationale would help users to understand what they could potentially do to positively influence energy usage levels, what is within and indeed outside of their control, and would also help them to gain greater understanding of the 'bigger picture' of energy use, in specific buildings and across the campus.

2. Design and Content

Providing comparative data emerged as a key recommendation. Providing energy usage data for individual departments within buildings (where possible, depending on metering capabilities), with the ability for users to select their own buildings to focus on within the app, would increase the relevance that users would feel the information had for them (since they would be able to see how their own department was performing), and would also enable users to compare their own department's or building's performance with that of others, thus creating a positive level of competition to help motivate users and promote behaviour change in relation to energy use. Comparative data would also allow monitoring of energy performance, within groups and between groups, over weeks or months as appropriate. This competition element could also possibly include 'league tables' to communicate how groups are performing, with rewards and recognition for those who are performing the best in comparison to either previous building energy levels, or compared to other groups.

Enabling the app 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 felt that, currently, the link between the app's content and how to save energy is not clear. Providing hints and tips to encourage users to question their behaviour (e.g. "Have you switched off your monitor?") would also equip users with the procedural information to take action to influence energy use. Furthermore, the ability to send prompts or alert messages would also be useful for security staff, to help monitor potentially 'abnormal' energy use overnight within DMU buildings.

Participants shared various views on whether the use of the endangered species was the most effective way to communicate the importance of the energy use messages to users. Participants mentioned that the animals may be perceived as too childish and would perhaps only appeal to children or younger people. The idea of using animated people, with happy, sad and neutral facial expressions, or showing them as ranging from healthy and happy to unhealthy and sad, were all ideas worth further consideration. 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.

3. Functionality

Having a 'map' of the Campus and buildings as the 'front page' display was suggested, with the emoticons (smiley faces) also featuring on this screen to give an immediate overview of energy use levels across the campus, with this clearly labeled or shown as 'live' data. From this front page it would then be possible to select buildings to look at in more detail. In relation to the functionality of the app, clarity of information being presented again was a key recommendation. Participants commented on the need for both the graphs and the animals to be easier to understand, with the possible inclusion of tutorial or guidance information to assist users in navigating through the app effectively. 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.

In considering attitudes towards the app, a key question raised by the focus group participants was "Will the app engage the unengaged?" One key way of enhancing engagement was thought to be the inclusion of more, or ideally all of the main campus buildings. In addition, providing feedback (e.g. of amount of energy saved) was considered likely to be more effective if the value of the saving was communicated 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). Providing the ability for users to be able to give feedback (e.g. using a forum, an active twitter link and feed, guidance on where to ask questions, who to phone or email), were also seen as ways of positively influencing users' attitudes towards the app, through increasing individuals' knowledge and understanding of the information presented and what they can do to respond to it.

In addition, if the app were expanded to include additional university campus buildings, it could help promote behavioural change with regard to energy use, and this was seen by participants as especially valuable for those areas or buildings where other initiatives focused on energy saving have not been successful in the past. The provision of procedural information (i.e. what individuals can do to influence energy saving) was also seen as a way to positively influence individuals' attitudes towards the app and towards energy saving, since this guidance would prompt people to act and to begin to establish new patterns and practices. Similarly, the inclusion of key messages being fed through the app from senior management (e.g. through an email link), demonstrating top level commitment to addressing energy use in the buildings would also be a welcome addition to the app for influencing how individuals view energy saving within DMU.

IV. IMPACT

The Greenview project has had a significant impact on DMU and its approach to energy management and visualisation as well as staff and student engagement. There is a general increased awareness of energy efficiency across the whole campus: the app has been downloaded by 139 staff and students across the campus and our twitter account attracted 131 followers.

A ‘go-green’ week was launched in September 2011 to encourage staff and students to reduce energy consumption by up to 25%. The Greenview team was invited to design a simple web version of the app to both monitor and communicate the savings to all staff and students. This resulted in a 13% reduction in savings based on the same week the previous year and was an excellent opportunity for the team to hone the methodological approach for measuring comparative savings.

If further funding becomes available, then we intend to address these valuable observations. Implementing these ideas into the design of the Greenview app will certainly help promote engagement with the tool and help promote behavioural change with regard to energy use across DMU. Hopefully, this over time will also lead to a gradual shift in attitudes, habits and practices, with a shift towards a more sustainable, energy saving culture in the University.

In conclusion, for the Greenview app we found that 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.

Subject to further funding becoming available, we intend to address these valuable observations. This over time will also lead to a gradual shift in attitudes, habits and practices, with a shift towards a more sustainable, energy saving culture in the University. There is clearly a need for a web-based as well as (or instead of) smart phone accessibility and the need for two-way feedback and communications and increased links with social media. There is also a greater need to clearly communicate energy use using colour coding: red, amber and green traffic lights coding and arrows to show whether usage has moved up or down and communicating energy excesses and savings in units that are relevant and easily understandable to the user.

The research on this project will, we hope, inform and inspire other projects that harness the emotional power of empathy and identification in the development of user strategies for behavior change in environmental and other social contexts. In specific relation to the concerns of the Cyberparks network, we envisage engaging and motivating users, particularly children, in outdoor visualisations of data and information related specifically to Heritage, Nature and Sport. The clear identification with an associated *mascot’s* ‘Health’ and the linking to social media via the Greenview app, provide both a conceptual model and strategy for real emotional engagement with digital data representations and the encouragement of sustained concentration on otherwise bland or un-engaging information streams.

The live updating and comparison aspects of the project add a further layer of motivation to the process and we hope the lessons learnt will be utilised in the development of apps, for example, about the trees and plants and wildlife found in open spaces and their relative growth, health, etc.; or in the comparison of relative exercise regimes within sports-related activities in urban open spaces via similar apps. Cultural and Heritage trails in such spaces could also use animal and other avatars as guides and personalised emotional referents.

In 2012 the App won in ICT category in the EAUC Green Gown Awards out of a National Competition.

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