IREEN Project

Living labs: Successful User Engagement on Energy-efficiency through Participatory Innovation

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Abstract: Research carried out by De Montfort University, UK, has identified a link between user-involvement in design and development of energy-efficiency visualisation tools and their successful adoption. Combining a living lab approach to innovation with social media creates the possibility for user involvement in very large numbers, including city-scale communities. An analysis under the EU project IREEN (ICT Roadmap for Energy Efficiency Neighbourhoods), shows these findings to have significant implications for innovations in ICT for enabling energy-efficiency at the neighbourhood scale. It also contributes evidence in support of using ICT to enable users themselves to increase their energy efficiency rather than automating control away from the user, concluding that the former approach can achieve cost-effective, sustained savings that increased automation is unlikely to do.

Introduction

This paper discusses the findings of research conducted by the Institute for Energy and Sustainable Development (IESD) at De Montfort University (DMU) exploring the impact and opportunities of using graphical visualization techniques to enhance user engagement with energy use. The continuing research is aimed at enabling users both to understand the environmental impact of their activities and to act through the social media applications of the digital technology. A series of studies were carried out on a campus level incorporating a 'neighbourhood' of buildings. This study assesses their knowledge contribution towards the development of an *innovation roadmap* under the EU-funded Project 'ICT Roadmap for Energy Efficient Neighbourhoods' (IREEN). *The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 285627.*

The key implications for innovation management (IM) relate to a greater potential impact of ICT on energy efficiency by involving users in a participatory innovation process. This involvement helps develop a sense of ownership and empowerment in the users that results in their commitment to actively using the software tools to generate savings. The engagement of users in a social process to tackle energy efficiency targets, linking all users to decision-makers and management, creates a living lab platform for continuous development of software tools. We discuss the role social media can play expanding this engagement across entire neighbourhoods and communities.

By focusing on individuals moving between buildings and communicating to them through familiar ICT media of social networks and smartphones, these projects made initial steps towards an integration of connectivity with energy use and creating neighbourhood energy communities. The results inform the development of a flexible, dynamic communications infrastructure between buildings and individuals and hence assist market development of ICT innovation in this field.

The aim of the IREEN[1] Project is to develop a strategy for 'European-scale innovation and take-up in the field of ICT for energy efficiency and performance in large areas'. As part of this process, IREEN is supporting research work concerning the production and dissemination of results describing state-of-the-art (ICT-based) supply-side solutions and best practices, coupled to demand-side visions and scenarios. The IESD research detailed below provides valuable insight into applications of Smartphone technology and social media to aid creation of energy efficient neighbourhoods (EENs) and workspaces, paying particular attention to the necessary ICT for collection, meaningful analysis and representation of the data alongside real-time communication of energy data where possible.

IESD has conducted a series of studies into the visualisation and communication of energy use, beginning with exploring the impact of the Energy Cities CYBER Display project and the role of Building Energy Performance Certificates (Bull et al, 2012b). Following on from positive results regarding user engagement, the Deliberative User Approach Living Lab (DUALL) was set-up to investigate whether involvement in the design of ICT-based user interfaces can affect behaviour change towards energy efficiency. It utilised a socio-technical solution to the design of a simple web based information-feedback tool that to report electrical consumption back to users. Its successor, *Greenview* continued this development towards a Smartphone app-based tool to connect staff and students to energy consumption of their buildings on campus.

Most recently, DMU has been awarded funding for *Gooddeeds*, an 18 month research project funded through the UK's Engineering and Physical Research Council (EPSRC – Grant no.EP/K012312/1) based at the university. Funded through the EPSRC's Digital Economy stream *Gooddeeds* aims to research the opportunities for and impact of these digital technologies on user-behaviour and energy demand reduction in the non-domestic setting through enabling building users to both understand the environmental impact of their activities and collaborate in networks through social media applications. It builds on two previous exploratory projects funded through JISC[2], *Greenview* (Bull, Everitt et al. 2012) and DUALL (Bull, Brown et al. 2011).*Gooddeeds* will also investigate further the social-network aspect and ways to incorporate energy controls within the app, plus how to collect data on behavioural responses and the resulting energy impact; Also being looked into the opportunities for spreading the app's reach into the city of Leicester.

Background and Motivation for the Study

The European Commission's Smart Cities Initiative invites cities to commit to 40% carbon reduction targets by 2020 by exploiting their natural interconnectedness enabling initiatives to spread rapidly around the population and deliver significant impacts. One such measure is energy-reduction through behaviour change enacted by demand-side management (DSM) and smart metering/communications. This is significant given the pressing legally binding and ambitious targets the UK has set for greenhouse gas emissions, specifically a reduction of at least 80% by 2050. Cities and the built environment that dominates them has an important role to play if the UK is to meet this target with almost 20% of the UK's energy consumption and CO2 emissions arising from non-domestic buildings.

The role of ICT and the digital economy offers significant potential to contribute to these carbon reduction targets within buildings. Latest reports, for example, SMART 2020: Enabling the low carbon economy in the information age (The Climate Group, 2008) highlight opportunities for ICT to create SMART buildings developing increasingly sophisticated (and expensive) building energy management systems (BEMS) to centrally manage the thermal comfort of buildings. Recent research (Darby, 2010, Hargreaves, 2010) has also explored the benefits of visualization tools, that is, presenting the energy consumption of buildings to the building users in an attempt to change their behaviour.

This highlights a key issue for the IREEN agenda: is energy-efficiency greater through automated control of buildings, transport and other energy-using services? Or are the overall savings greater if users are themselves engaged in the energy management processes – incorporating the potential for behaviour change in one arena (e.g. workplace) to be transferred to another (e.g. home) or between individuals with influence in different work areas, a key aspect of neighbourhood level analysis of IREEN. As Bull et al (2008) demonstrated "participation has gone on to affect their social networks, colleagues and neighbourhoods”. ICT is traditionally considered a driver of the former solution. In this case, we explore how it can contribute just as significantly to the latter.

How to engage the public is a major issue in both the innovation and energy efficiency sectors. Participatory approaches are gaining popularity in a society where trust in authority and top-down approaches is falling (Webler et al, 1995, Bull et al, 2012a, Kubatova, 2011). By incorporating public engagement in innovation, such approaches enhance democracy in decision-making (Webler et al, 1995). Moreover by both making technical knowledge publicly acceptable and bringing practical day-to-day issues and opinions into an expert discourse (Petts, 2006) participatory processes deliver superior outcomes (Pianosi et al, 2012), illustrated by experiences of involving users in ICT innovation (Schuurman & De Mazer, 2010). Previous studies, in the field of mobile communications on energy use data, had indicated the twin benefits of exposing users to a functioning prototype, that it provides crucial feedback to aid software development while allowing users to better understand its usefulness (Weiss, Loock et al. 2010).

ICT and particularly Internet-based industries have long embraced a more open, participatory approach to development (Malone, 2004, Leadbetter & Miller, 2004). The block by block nature of computer programming and the continuous process of review and update, plus the ability of programmers to edit others' code lends itself to an open approach. In this context, Web 2.0, where all users are both consumers and content providers – *produsage* (Bruns, 2011) – is merely a natural progression. The opening up of these approaches to other sectors, through the broad reach of Web 2.0 and social media is potentially an opportunity for change at societal level.

Yet how might this change be enacted? Social media is beginning to be used to harness public engagement on key scientific questions, of which climate change/energy efficiency is one, to enable public to support experts and contribute to scientific processes by, e.g. data gathering (Stewart et al, 2012). There is as yet a lack of research to demonstrate that social media can effect behaviour change and the specific question remains whether technology is the most appropriate method to engage people in pro-environmental behaviour (ibid).

This latest point is perhaps best interpreted as justification for further work, rather than a strong claim against technology's use in this way. Christakis (2008) refers to behaviour change spreading through social networks as a social contagion, due to our understanding of social norms being variable on the behaviour of friends and others that influence our choices, often on a subconscious level. Social networks – online or offline – play an important role in facilitating and supporting participatory approaches by linking communities, neighbourhoods and other groups to in turn generate opportunities for 'getting involved'. In fact: "the ‘link mechanism' is one of the most powerful mechanisms of social networks" (Pianosi et al, 2012). Specifically to this work, social media offers the possibility of reaching many more of the city neighbourhood's relevant actors virally, through existing social links, hence requiring limited investment, and extending the living lab over a much broader population of users.

Increasingly Smartphone-based 'applications' are being explored as effective tools for energy behaviour change (Lehrer and Vasudev 2010; Weiss, Loock et al. 2010). Designers from the *Low2No* project (Experientia, 2011) recognized that developing energy awareness and engagement applications for smartphones can drive the impact further: as the device is more personal both in terms of data and emotion, the way in which people interact with the Smart System can be made more spontaneous and enjoyable. The dynamic nature of smart communication enables the app to form both the communication & engagement tool and, with the user's permission, record the users' reaction to communications in terms of energy-related behaviour. By further incorporating a form of social network within the app, data can also be gathered on how one individual's behaviour influences another.

The motivation for this study can be summarised in the following three questions. Firstly, what role for the citizen in reducing the energy demand of the buildings and neighbourhood within which they find themselves? In their workplace for example are building users able to exercise autonomy in controlling their physical environments? Second, does it matter how these messages are communicated, for example, presenting electricity consumption in traditional units of measurements or are there more innovative ways of engaging building users? Finally, the accounting of energy/carbon reduction in order to demonstrably achieve the ambitious reduction targets needs to be fully understood so we can accurately lay claim to improvements and apportion responsibilities. The last two points have implications for the Innovation Management (IM) industry in terms of providing an infrastructure through which to deliver the solutions.

The IREEN Context

The IREEN project includes a taxonomy matrix (Fig. 1) as a structured approach to aid classification of priorities for ICT R&D supporting energy efficient neighbourhoods (Zarli et al, 2012). It features complimentary axes of technology and application areas, which are grouped into categories. The key technology categories explored by the IESD research are *Decision Support*, regarding the use of ICT to deliver innovative visualisation of energy use and consequently lead behaviour change; *Energy Management*, due to the use of intelligent and dynamically interacting monitoring and control; and *Integration technologies* focused on benefits through knowledge-sharing and communication.

There are two key application areas for this study. The *Built Environment*, but crucial to the IREEN objectives, research initially focused on one building has been extended to multiple buildings at campus level. It presents the opportunity for knowledge gained at one location to be applied at another, shared through the system by way of social links, using the social media element of the tool, not just traditional procedural communication within the university organisation. The social media element, along with the deliberative approach outlined later, encapsulates the *People Involvement* application area.

The outcomes of the IESD studies are used to derive from the ICT-based interaction of the users with the university a generic neighbourhood scenario which, under IREEN, is used to describe market expectations for future developments and technologies. The scenario created is a Social Network System (SNS) to connect users of a neighbourhood of buildings and services to the energy use impact of their activities both within and between different buildings. The context is a mainly workplace & education scenario (university campus) and the ICT potential is further advanced by collecting data on the social network to evaluate behavioural and energy impacts.

	Application Areas																				
	Neighborhoods - Urban and Rural Communities																				
	Planning, Operation and Maintenance	Transport			Building, Infrastructures & Open Spaces							Energy Production & Storage			Energy Distribution			People Involvement			
Technology Areas		Public transport	Transport Infrastructures	Electric Vehicle Networks	Public & institutional buildings	Residential buildings	Offices, commercial and industrial buildings	Parks, squares, greenery and open spaces	Public Lightning	Water and Waste Management	Farms, ranches and small rural businesses	Holistic energy systems	Electrivity production & storages	Heating and cooling production & storages	Electrical power systems	District heating & cooling systems	Gas network	Civic commitment & public participation	Public information, education and training	Privacy and security	People behaviour & consumption patterns
Design, Planning & Realisation																					
Design																					
Modelling																					
Performance Estimation																					
Construction and Maintenance Management																					
Decision Support																					
Performance Management																					
Visualisation of Energy Use & Production																					
Behavioural Change																					
Energy Management																					
Intelligent Monitoring and Control																					
Energy Brokering Systems																					
Energy Hub																					
Smart Grids																					
EE Services: business concepts and financing																					
Integration Technologies																					
Process Integration																					
System Integration & Open Data																					
Interoperability & Standards																					
Knowledge Sharing																					
Virtualisation of the Built Environment																					
Communication																					

Fig. 1: The IREEN taxonomy matrix

Methodology: Living Lab approach

The IREEN project includes elements of a Living Lab approach, as defined by Følstad (2005), primarily conducting research in real world contexts in order to tackle the real world problem of needing to increase energy efficiency. Rather than setting out a separate research plan to collect data for independent analysis to create a theoretical view of an ICT-enabled energy efficient neighbourhood, case-studies were sought of innovations being implemented in the field. Not only the results are evaluated, but also the participants in the case-studies are engaged in the IREEN research process, contributing directly to its output. This dynamic interaction provides the project with real world feedback on innovations, while also disseminating findings into the field during the project lifetime, not just on completion.

The collaboration with IESD on this paper is one example. The results presented challenge an assumption that automation of energy management, provided by technological innovation in ICT, is the route to energy efficiency. This assumption is based on an ‘information-deficit’ model by which users are unaware of the impact of their actions on energy use, or that they as individuals are powerless to influence energy use in a large building. Automation is viewed as an easier solution than rectifying those two problems. This research reveals that barriers to energy efficiency are more varied and context-dependent than a simple lack of information. A process of user involvement, developing innovation in real world context, delivers a greater impact than a standard automated control solution by exploiting local knowledge and preferences to specify context-specific measures.

The DUALL (Deliberative User Approach to Living Lab) project aimed to uncover whether involvement in the design of ICT-based user applications can affect behaviour change. Building users were involved in a deliberation process in which they were consulted on their preferences for being informed of energy use data. To accommodate a wide range in the responses, the interface was given two dimensions: a sophisticated reporting software to enable those actively involved in energy management to act; and a more accessible visual available on all pc's displaying current departmental energy use (Bull et al, 2011).

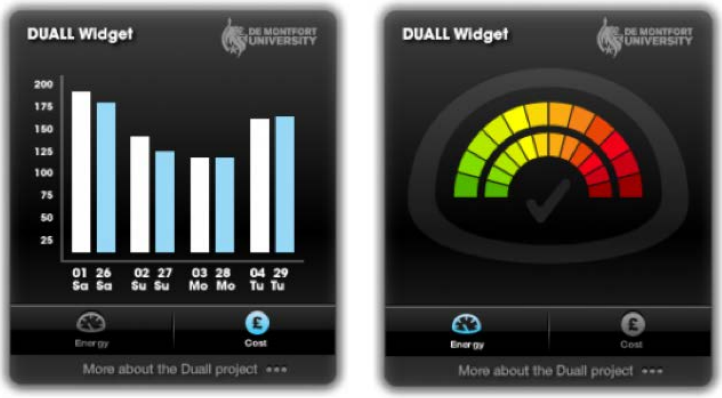

Fig. 2: The DUALL Widget

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, enabling staff and students to not just see the energy performance of every building, but then to use the link to the social media platform, Twitter, to map issues, and share ideas and recommendations on how best to manage energy consumption in University buildings (Bull et al, 2012a). Analysis created a dynamic comparison of each building's historical consumption against live data and placing current consumption in one of three 'zones' depending on whether it is above average, below average, or normal – compared to the equivalent time last year. (See Fig. 3)

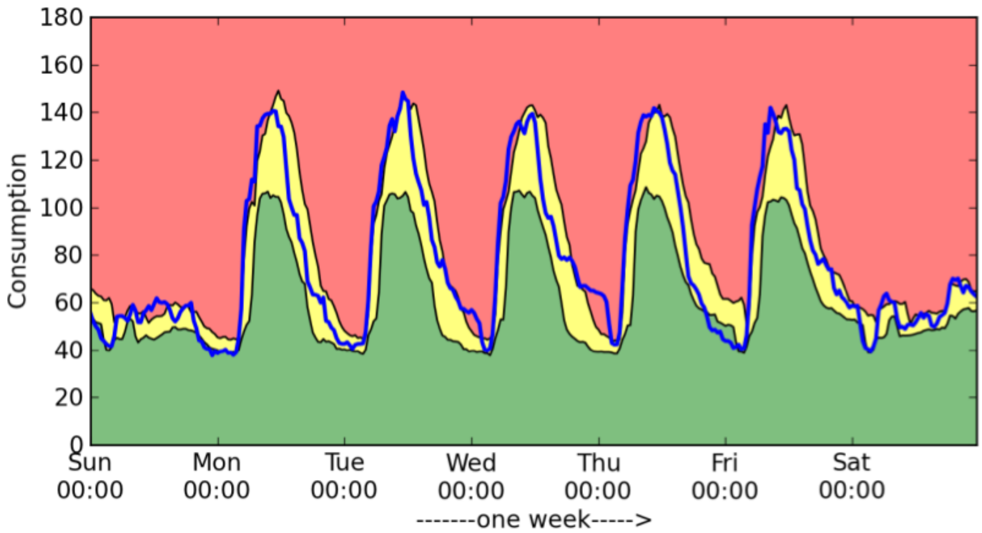

Fig. 3: An example week plotted (blue line) against the three consumption 'zones'

An important advantage of this approach is that it continually 'moves the goalposts' of *normal* performance, meaning further improvement is always encouraged. Performance improvements are incorporated into normal performance a year after implementation. In this manner, the simple visualisation remains valid and relevant to users and reflects the marginal impacts of their (combined) actions at any given moment.

The software tool communicated the three states of energy performance as good, neutral or bad, through animations of the buildings expressing emotions at their current performance. To add an extra educative layer to the visual engagement, each building was 'occupied' by an endangered animal species.

Fig 4 (right): Greenview App 'Front Page' illustrating the five buildings' current state

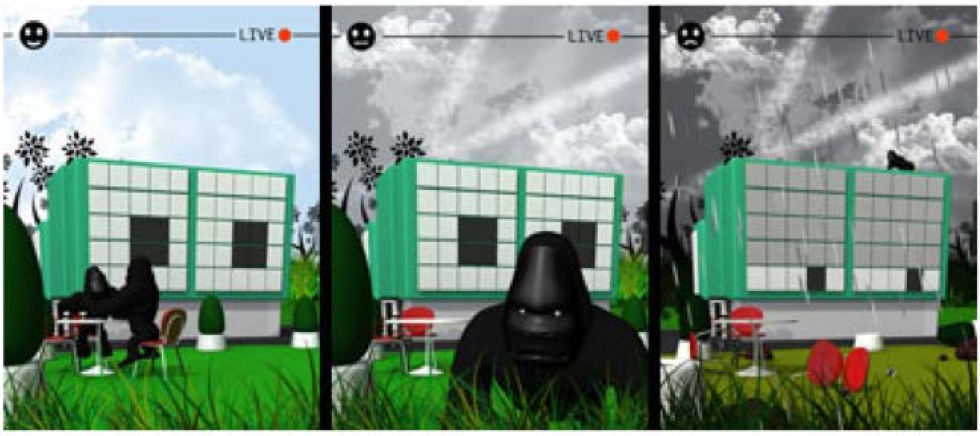

Fig. 5 (below): An illustration of the three states in one building, from left – 'happy', neutral and 'sad'

Data has been collected on the responses, both in thought and in action, of users accessing the software by surveys, interviews and independently facilitated focus groups. This has led to the University sustainability team now managing its own Twitter account and experimenting with social media to engage staff and students.

The IREEN research focused on the approach to tackle directly the issue of perceived powerlessness of the individual to influence energy use at neighbourhood level, in this case staff and students. Creating an online social media forum on which all users can freely exchange views with colleagues, staff and the energy managers, would enable users to influence decision-making. On one hand it utilizes the 'power of the crowd' (Pamlin, 2010) whereby users can collectively put pressure on managers to carry out measures they feel will have a positive impact, simply by engaging in a visible discussion on the forum. On the other, it puts users in direct contact with decision-makers.

Example Scenario: Tom, a media studies student, notices that a lecture is taking place in an old hall far too large for the class. The hall is always too cold at the beginning and too warm at the end, due to the heating system specified for a high occupancy that has to work at constant full power to heat the half-empty room. By pointing this out to the course manager in a tweet to the , the class is rearranged to take place in a smaller room, available in a newer, more efficient building on campus, improving both comfort and energy efficiency. Tom was more confident to raise the problem on social media than directly and because the discussion is under public view, receiving staff support in the form of retweets, the course manager felt obliged to act. It also led to a follow-up discussion between several students that they all have to travel to campus on that day only for that one lecture, and that it would be better on another day, when most are already on campus for other classes. An quick survey on Twitter, joined by the professor, uncovers a free timespot on a busier day, which suits all, thereby reducing travel and transport demand.

The communication through Twitter followed to some extent the Lead-User concept (von Hippel, 1986) whereby initial analysis of impact of the *Greenview* interventions focused on the twitter networks of the top 25 social media users at the University (Pianosi et al, 2012). Analysis tested for an increase in 'conversation' involving relevant keywords such as energy use, pollution, environment, etc. What can be inferred from this approach is an expectation that the top social media users will lead the discussions on the effectiveness of the tool and towards potential user actions. In this way, they participate in the innovation process 'by proxy' (Urban & Von Hippel, 1988 in Schuurman & De Marez, 2010) even if they don't themselves engage in product development.

Two further points illustrate a development in research practices of opening up the research to feedback from the public domain while it is still in progress, thus incorporating social elements into all stages of the innovation. The programming used the version control software GIT and was conducted via the GiTHub open coding platform (https://github.com/DaveEveritt/Greenview-App). The finished app (latest version) was made available to all on iTunes App Store, plus through the Greenview website. During the 6-month period of research, the app was downloaded 139 times (Bull et al, 2012a).

Results

The research continues to produce positive results, if not yet definite proof of a sustained energy-efficiency impact. The DUALL project reported reductions in the baseload and overall electricity consumption during the research period. The *Greenview* project recorded savings of 13% from its use as part of a campus-wide event to promote energy-saving (Bull et al, 2012a). It also reported positive feedback on the visualisation of energy use through emotive images (ibid). These provide a useful departure from previous studies suggesting comparison of current with historical performance is not rated highly useful by users (Weiss, Loock et al, 2010) that this depends somewhat on how this data is communicated.

Though nothing like the behaviour change scenario described above was observed, the first steps towards achieving impact on that level were laid out. During the promotion period interest (131 Twitter followers) and energy-saving (13% reduction) were high (Bull et al, 2012a). User responses were positive to an attempt to engage with them on energy in an entertaining way, but suggested that only with more levels of interaction could the app sustain interest and use (France, 2012). The ability to interact through the app on social media, to get procedural information on what individuals can do to influence energy saving and to have contact with senior management (decision-makers) were all recommendations for improving the app generated by the focus group (Bull et al, 2012a).

The reactions to emotional buildings are not linearly predictable however, highlighting the importance of dynamic interaction to reward actions with a positive impact and discourage actions having a negative impact. Comparative feedback between buildings within a neighbourhood was shown to be an important driver of user action, emphasising the key role of the social media aspect in generating an active response, plus the possibility to add 'game features' to sustain use of the app.

IESD is focusing further work - notably on the forthcoming projects SMARTSPACES[3] and Good Deeds, on creating interfaces that exploit emerging trends in use of ICT, wifi networks, smartphones and social media applications, rather than introducing new innovative technology, in order to optimise user accessibility and reduce the risk of non-adoption. The interfaces will require continuous innovation to retain currency with the latest ICT preferences, again emphasising the value of the long-term living lab approach.

The choice of a multi-dimensional interface demonstrates an important benefit of the deliberative living lab (DUALL) approach: by engaging with users in different ways to which they are individually responsive, brings energy into a public (users) discursive process which, by increasing the imperative on energy managers to act, also increases the energy reduction impact (Bull et al, 2012b). It also demonstrated how the use of augmented reality techniques to present information based on personal perspectives helps optimise response levels.

Both DUALL and Greenview received lower than hoped-for initial participation levels. For DUALL it was difficult to find sufficient staff, outside of those directly connected to the project to take part in pre-development discussions on the software tool (Bull et al, 2011). Social media discussion of Greenview was limited to a few actively engaged individuals (Bull et al, 2012a). Though this mostly reflects practical limitations on staff availability for non-core tasks and on the scope for promotion within the project budgets, there may be more interesting factors at play. Negative feedback informing revisions to the innovation is a core element of the participatory approach.

Implications for IREEN & IM Industry

The projects have not yet shown that Smartphone and social media-based communications can lead to behaviour change to reduce energy consumption, nor were they expected to. What has been achieved is an exploration of the mechanisms for engaging users through innovative visualisation techniques, based on user preferences, by involving users in a participatory approach to innovation. Further, by using social media to expose these advances to real-world, public examination, it has further demonstrated the potential for social media engagement to extend living lab style innovation to wider participation – potentially incorporating the majority of a neighbourhood community.

In terms of the IREEN aims to guide future innovation in ICT for energy efficiency, this work makes an important contribution to the discussion over greater automation versus greater user involvement, significantly in support of the latter. Previous studies (Weiss, Loock et al, 2010) suggest a combination of automation and 'user-in-the-loop' approaches, but the DUALL project generated substantial savings through user action on out-of-hours energy consumption (Bull et al, 2011). In that particular case, the reduction was due to face-to-face conversations between staff with access to the energy manager. Social media extends the possibility for such a discussion to include students and other users, even visitors. Plus the public visibility of what is being said, and by whom, encourages support and discourages a negative response from decision-makers. The following step to enhance the engagement tool to enable suggestions of potential user action will also test its overall effectiveness in delivering actual savings.

The simplified engagement approach allows for extension to neighbourhood scale by adding other buildings, including residential, plus service networks, e.g. transport. There are however several challenges to this method being extended to incorporate an entire neighbourhood, whilst sustaining impact. On one hand the review reported a need to separate the energy data out to department level, to reflect impact of individual or working group actions. On the other hand, to overlay data from several buildings to create a personal energy impact profile for individual users that remains meaningful. Further the task of installing metering, data management and communication hardware that provides data in a consistent, comparable and meaningful format from all energy use nodes requires significant collective investment.

Another benefit of the approach is that negative results, such as lack of interest referred to above in Results, informs development in a way that may not have been possible in a test setting due to the obligation to participate fully in spite of a lack of personal interest. In the real-world context of the Living Lab those managing the innovation are forced to include flexibility to be able to adapt to negative reaction in order to achieve optimum adoption levels.

The positive impact of the Living Lab, whereby the innovation is refined through a participatory approach to mitigate initial criticism is a key finding for the IREEN roadmap to guide ICT innovation for energy efficiency. It suggests that to optimise ICT innovation for energy efficiency, genuine engagement with building users must begin at the R&D stage, not just as consultants, but as actors implementing the ICT measures to improve energy efficiency in real world contexts. It is the very involvement of the users that enables the measures to be successful.

Future research will hence focus on expanding user involvement through social media to include neighbourhoods outside the university to see if this brings similarly extended impact on energy efficiency. It should be expected that the solutions developed in a participatory process in Leicester will to some extent reflect the specific characteristics of the city. Through the IREEN network the principles of participatory innovation can be further applied to develop solutions for other cities and neighbourhoods that are specific to them, hence replicating the process, rather than applying a one-size-fits-all solution that may only be effective in certain contexts.

Notes:

1. The research leading to these results has received funding from the European Union Seventh Framework Programme ([FP7/2007- 2013] under grant agreement n° 285627. The IREEN Consortium is formed by the following partners: City of Manchester, CSTB, VTT, D'Appolonia, AIT, ATOS, ACCIONA, and Green IT Amsterdam). The project duration is September 2011- November 2013.
2. 'JISC' (the acronym once stood for 'Joint Information Systems Committee', it is now their name) inspires UK colleges and universities in the innovative use of digital technologies.
3. 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.

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