ICT for sustainability: reflecting on the role of ICT to enhance communication and empowerment of building users

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Abstract

ICT solutions within a Smart City environment are often hailed as the low carbon, efficient and low-cost solution – but is this sufficient? These solutions often neglect user behaviour and treat users as passive consumers or even obstacles. Energy related ICT behaviour change is also starting to appear more frequently at the forefront of policy agendas and research funding calls as a prime focus for reducing energy consumption and improving efficiency across all energy intensive sectors. Research shows that improving and widening user engagement has the potential to foster greater acceptance and impact. Recent research has focused on behaviour change towards more sustainable energy use, often involving users co-designing interventions. As such, ICT is a prominent tool, with its application including feedback tools, apps, interactive dashboards and gamification. Frequent barriers are user engagement with ICT tools, both initially and over the long term, with research consistently showing that users are hard to engage, face a complex array of competing demands and easily become disengaged with energy programs and interventions.

This paper presents a summary of some of the common problems relating to user engagement with energy interventions faced by many research projects, as well as presenting findings from eTEACHER, an EU H2020 project, aimed at empowering energy end-users by enabling behaviour change via a set of ICT solutions. eTEACHER, aims to employ principles of user-involvement and engagement to enhance the design of an ICT-based tool promoting energy conservation in buildings. eTEACHER has applied the 'Enabling Change' framework as a novel approach to ensure user engagement and stakeholder involvement. Results and reflections are offered from eTEACHER's implementation of the Enabling Change framework and the engagement of building users within the eTEACHER pilot buildings, surrounding the design and implementation of an ICT-based tool. Reflections are given throughout on rethinking how we engage with citizens and our success in identifying, engaging and eliciting feedback from building users. The real-world issues and constraints are explored alongside, and opportunities are identified for improving energy efficiency using an evidence-based intervention design in practice and discusses how ICT can aid the empowerment of building users towards their own energy use.

Introduction

In the context of behaviour change and energy efficiency in buildings, information and communication technologies (ICT) have increasingly been used as tool to provide information or 'feedback' to building users. This can be achieved via display monitors, building energy management systems (BEMS), interactive dashboards and a range of web-based apps that make energy visible to building users (Bull et al., 2013; Bedwell et al. 2014; Bastida et al. 2019). Previous research has shown that whilst feedback does offer potential for reducing consumption, between 5–15 % on average (Burgess & Nye, 2008), there is no simple cause and effect between installing ICT enabled feedback and subsequent behaviour change by building users. In response, there are increasing calls to move beyond feedback and appreciate the wider social, organisational and cultural context of energy use in both the home and workplace (Bull & Janda, 2018; Hargreaves, 2018). Moving beyond 'mere feedback', there are examples of exploratory studies that examine the potential of ICT and tools such as social media for behaviour change within energy and buildings (Lehrer & Vasudev, 2010; Foster et al., 2012; Burrows et al., 2013; Crowley et al., 2014). Involving users in the co-design of interventions is an increasingly popular strategy to enhance the acceptance of ICT-based tools to promote energy conservation in buildings. To do so requires organisations to adopt a more participatory approach to energy management (Janda, 2014; Moezzi & Janda, 2014). In a comprehensive review of over twenty energy and behaviour change interventions in the workplace Staddon et al. (2016) note that the most successful initiatives had a combination of technological automation *and* 'enablement' – that is, opportunities for building users to move beyond education and training.

This paper responds to this context by discussing a European Union (EU) Horizon 2020 (H2020) project, eTEACHER, which is employing principles of user-involvement and empowerment to enhance the design of an ICT-based tool to promote energy conservation in buildings. eTEACHER will develop and pilot an ICT-based engagement tool over three years, working with twelve case study buildings, including domestic and non-domestic buildings, in the UK, Spain and Romania. The paper aims to explore the practical benefits and limitations of a user engagement approach based upon initial findings from consultation events and site visits conducted over the past year. In doing so, it adds to the literature on effective design of ICT-based interventions for energy conservation, and on effective approaches to citizen engagement within building communities.

Background

The emergence of ICT in recent years has brought with it a wealth of opportunities to both manage energy efficiently in buildings, and to intervene to promote energy efficient behaviours. This section first considers the domestic context before considering how ICT tools have been applied in the non-domestic or commercial environment.

A large proportion of energy behaviour change interventions and the provision of feedback have focused on the domestic setting and, particularly, the implementation of In Home Displays (IHDs). These are frequently used in homes to provide near-real-time consumption data and have achieved electricity consumption savings of up to 14 % (Murtagh et al., 2014). However, there are also many revealing inconsistent results. Hargreaves et al. (2010) attributes the differing degrees of user engagement with domestic displays to the varying constraints of social relationships and practices in different households. Buchanan et al. (2015) supports the notion that feedback alone is insufficient to rising carbon emissions and energy demand, pointing out that short-term reductions are only 2 % on average. In spite of improving knowledge and confidence about energy consumption, IHDs do not always motivate residents to decrease their energy use as they blend into the background (Hargreaves et al., 2013). Studies investigating the appearance of IHDs have found greater acceptance when they fit into users' routines and home aesthetic (Wilson et al., 2010 and Riche et al., 2010). Weiss et al. (2013) suggest the use of smartphones over IHDs, emphasising that most individuals already own and use them.

Non-domestic buildings are also an important priority for research as they give rise to approximately 18 % of the UK's carbon emissions (Bull & Janda, 2018). In a field trial of individual energy use in offices, Murtagh et al. (2013) showed that energy use in office computing contributed approximately 30 % of energy demand in the European service sector over the last decade. Research by Mulville et al. (2014) highlights that much of this equipment is under-utilised and frequently left on overnight. The workplace offers new opportunities for energy feedback, such as via display screens in communal areas which have been used in a range of projects (e.g., Timm and Deal, 2016; DECC, 2018), though their impacts on energy saving remain unclear (Staddon et al., 2016). Behaviour change interventions within workplaces face additional considerations such as the agency of building users, organisational decision-making process and the roles of "middle-actors" (Parag & Janda, 2014).

Sustaining engagement with ICT-based interventions such as home energy monitors and web-based apps can prove challenging, and gamification has emerged as one potential solution. This can include 'serious games' that aim to be both entertain and educate (Ritterfeld et al., 2009) and using motivational aspects of games to improve the engagement and experience of users in other types of interaction (Deterding et al., 2011) to make an activity more fun (Grossberg et al. 2015). This could be as basic as a point's competition between buildings or neighbourhoods, or as sophisticated as an app with energy avatars. Johnson et al. (2017) report gamification to be valuable in striving to achieve energy conservation. In fact, many energy-focused gamification apps have reported success in raising energy awareness (Banerjee & Horn, 2014), generating positive attitudes towards energy saving (de Vries and Knol, 2011) and improving energy-related knowledge (Geeleen et al., 2012). Grossberg et al. (2015) advise that the most fruitful game designs are fastidiously tailored to the specific user audience and integrate social media to reward efforts and amplify impacts. Wood et al. (2014) also highlight the importance of comparing performance socially, as well as improving energy literacy via applicability to physical energy use, and having clear, actionable goals. Senbel et al. (2014) learned that their success in reducing energy consumption stemmed not from the competitive point scoring against unknown peers, but in the communication of stories and experiences with personal friends. These studies therefore highlight that engagement can be supported and enhanced further through facilitating this communication within social networks.

Specific behaviours and behaviour change can always be understood as taking place within a 'wider system' (Michie, van Stralen and West, 2014), and this insight has particular relevance in the non-domestic sector. The concept of "building communities" (Janda, 2014) recognises that many behaviours are embedded in specific social and technical contexts, which warrant consideration beyond a focus on 'individual' behaviours. The formation of a community allows users to feel part of a collective effort that can amplify their impact. Given the increased desire to amplify social interaction within behaviour change interventions, it follows that social media could prove an invaluable mechanism for interventions.

This could be done through entirely new bespoke platforms, or by "piggybacking" on existing popular sites, utilising pre-existing habits of frequent engagement rather than attempting to solicit regular use of a new login and unfamiliar system (Mankoff et al., 2007). Examples have included incorporating social media platforms, using physical user meetings, providing feedback and allowing building users to flag issues and request solutions, (Crowley et al., 2014; Bull & Janda, 2018). Social media has also been used to launch and energise a competition between 6500 students at a University campus (Senbel et al., 2014) generating increased motivation through actions and stories of friends, opposed to scores of unknown peers. However, social media use is not without challenges, particularly within organisational settings where issues of privacy and trust can compromise a user's willingness to take part (Bull et al., 2015).

Increasingly, studies are recognising that the value in user engagement is not confined to evaluating the impacts of interventions; but rather, users' input during the entire design process may be a prerequisite for success. There appears to be a growing consensus that, for optimal success, the target audience should actively contribute from the early stages of development and then recurrently throughout (e.g. Wallenborn et al., 2011; Larson et al., 2013; Christina et al., 2014). In this way, the design is progressively refined to ensure the final output will accommodate the users' needs and wants, thereby maximising the chance of intensive and prolonged engagement (Yardley et al., 2016). Active user engagement during development stages points towards a crucial heterogeneity in the needs of different groups of building users, which precludes reliable success when blanket solutions are rolled out (e.g. Van Dam et al., 2010). Addressing all building users uniformly in spite of this fact is regarded as an oversight by Khosrowpour et al. (2016) who argue for targeted and tailored interventions that treat each group of users according to their characteristics. This sentiment is supported by projects, which place emphasis on the importance of in-depth user studies (e.g. Tang, 2010) and the crafting of personalised and context-aware interventions (McMakin et al., 2002; Bull et al. 2015; Lossin et al., 2016; Inyim et al., 2018).

Thus, whilst ICT-based behaviour change interventions for energy efficiency in buildings hold promise, they face specific challenges around motivating sustained participation, enabling interaction between stakeholders, and using principles of user engagement to enhance their design. The next section introduces eTEACHER which explores each of these challenges, and reports on the learning to date from engagement with building users on case study sites to enhance design of the eTEACHER web-based app.

Methodology

CASE STUDY PROJECT: ETEACHER

The eTEACHER project, **e**nd-users **T**ools to **E**mpower and raise **A**wareness of behavioural **CH**ange towards **E**ne**R**gy efficiency, is a H2020 funded project (GA768738) consisting of a consortium of twelve partners representing a range of expertise, across six different countries. eTEACHER aims to empower energy end-users to achieve energy savings and improve the health conditions and comfort in not only residential buildings, but also public office buildings, healthcare centres and school building. The project aims to enable behaviour change via a set of ICT solutions, including Building Automation Control Systems (BACS) add-on services and user-friendly solutions such as apps and dashboards. eTEACHER is being piloted with twelve pilot buildings (Table 1), varying in location, typology and building users. The potential for innovation here is twofold; firstly, in the development of an original, user-centred methodology to identify trends across building types and enhancing user engagement with the project; and secondly using subsequent insights to develop an ICT tool which will function in a wide range of contexts to support behaviour change towards energy efficiency.

To embed user-centred design within the project, the Enabling Change approach to behaviour change design (Robinson, 2011) was selected to structure development of the eTEACHER app and user engagement. The approach consists of two main frameworks for planning: *programme level* and *project level*. Programme level planning defines the medium and/or long-term objectives of the intervention via five main steps, involving preliminary scoping of available research and knowledge by including the target audience in focus groups and/or informal discussions. The Project level planning involves nine steps focused on the practicalities of carrying out the interventions on the ground, with an emphasis on ensuring the intervention is right for the target audience. This level not only identifies target actors and actions but also investigates the needs and concerns of stakeholders, considering ways in which the action can be more beneficial and easier to carry out. Ongoing involvement and engagement of target users is recommended through the creation of a 'Brains trust', an advisory group containing target audience members and other supportive stakeholders. Within

Table 1. Summary of eTEACHER pilot building characteristics.

eTEACHER pilot building	Location	Building use	Building type	No. of building users
InCity (4 separate blocks)	Bucharest, Romania	Residential	Private	1,500
Villafranca	Spain	Health Centre	Public	915
Guarena	Spain	Health Centre	Public	577
Torrente Ballester	Spain	High School	Public	120
Arco Iris	Spain	Kindergarten	Public	120
OAR	Spain	Office	Public/Private	130 staff + public visitors
Residential Block	Spain	Residential	Private	95
Council House	Nottingham, UK	Office	Public	40 staff + public visitors
Djanogly	Nottingham, UK	High School	Public	800

Table 2. Summary of initial building user workshops held.

Location	Pilot Building	Group size	Percentage of total users	User roles present	Demographics
United Kingdom	Council House	10	25 %	Admin staff, cleaning staff, City Councillor	Age range: 11–60+ Language spoken: English
	Djanogly	22 (over 2 workshops)	3 %	Teachers, other staff (e.g. admin, cleaning), students	
Romania	InCity	39 (over 2 workshops)	3 %	Facility manager, technical crew members, owners and tenants, building visitor	Age range: 18–60 Language spoken: Romanian
Spain	Torrente Ballester & Arco Iris	8	3 %	Staff and students (high school only)	Age range: Majority 40–69 Language spoken: Spanish
	Residential block	5	5 %	Building manager, facility manager, staff	
	Villafranca	9	1 %		
	Guarena	9	2 %		
	OAR	10	8 %		

eTEACHER, this principle has been applied via initial building user workshops and an aim to develop 'Feedback Forums' for each case study site for ongoing user engagement in the design and implementation of eTEACHER.

DATA COLLECTION

Given the complexity of different target users and building typologies within the eTEACHER sample and previous literature identifying that a "one size fits all" solution will not suffice, understanding the context of each pilot building and target user groups was of primary importance. Three complementary data collection methods were undertaken in the first year to collect relevant information: pilot site visits; building user questionnaires; and initial building user workshops.

Pilot site visits

Site visits were carried out in each pilot building, not only as a means to gather data on each building but also to better understand their users and the potential for implement behaviour change interventions. During the visits, five main areas of information were gathered to create a richer picture of each pilot building and some of the user behavioural issues. These addressed the categories of building users, including any influential "middle actors" (Parag & Janda, 2014); the primary function of the building; the energy systems and BEMS installed; energy use data currently available; and any distinctive energy-inefficiency behaviours currently taking place.

Building user questionnaire

Data on the target actors and their energy-related behaviours were collected from a user questionnaire, distributed to a representative sample of users in each building. The questionnaire covered seven areas: user demographics; ownership and use of ICT devices; use of the pilot buildings; energy-related behaviours, attitudes and awareness; thermal comfort satisfaction; users' motivation to engage with eTEACHER; and the impact of social norms on behaviour. These questions were informed by the 'COM-B' model of behavioural influences (Michie, van Stralen and West, 2014), which highlight that capability, social and physical opportunity and motivations interact to influence behavioural outcomes. In total 115 questionnaires were completed, representing 3 % of the total number of users in all eTEACHER pilot buildings. A second questionnaire is planned for later in the project, which will be distributed to all building users and should yield more representative response.

Building user workshop

An initial workshop was used as a means to build rapport with building users through activities based around ICT engagement. The workshop collected data on users' ICT practices and opinions on potential eTEACHER designs and functions. The workshops were delivered using a uniform template to generate consistently formatted results from the information generated during the sessions. Each session was designed for 8–12 participants, representing all user profiles deemed necessary – both those using the building every day and relevant facility management staff (see details in Table 2). Attendees were split into groups, each with their own facilitator to guide the completion of the workshop activities and facilitate discussions. Activities were designed to be colourful, hands-on and mentally stimulating, making the experience memorable and to form a positive association with the project, supporting continued engagement.

Results

BUILDING USER FEEDBACK WORKSHOPS

The user workshops identified several principles for design of the eTEACHER app. Common themes reported included the desire for simplicity and convenience so that the tool is not too onerous to use or understand. Building users also stressed the importance of flexibility, with many calling for elements of customisability, such as different layers, which can be expanded depending on the user's time allowance. Several users also expressed an interest in seeing real-time consumption, in an easy to understand format. Being able to see changes and gain a sense of achievement from making a difference was reported as supporting motivation.

Several potential barriers to take-up were also identified. A key barrier identified was limited time to use the app and what to do about non-participation from others in the building. In terms of gamification, most users did not wish to engage with eTEACH-

ER as 'a game' to be played, as this was perceived as wasting time when they have higher priorities. However, users were open to the app having game-like elements to motivate use. There was caution about game-like elements such as competitions, which could be potentially unfair given the different time and energy demands of different job roles. Most users were not interested in feedback on the carbon footprint of their behaviour, but data on energy use and money savings were often of interest.

A key insight identified regarding the opportunity to use eTEACHER was that school students are not permitted to use smartphones, therefore prohibiting their use of an app-based tool. Similarly, energy facility staff members in one building did not have access to a smartphone. This points to additional ICT devices (such as tablets, PCs and screens in communal spaces) being used for eTEACHER alongside smartphones.

Users were given the opportunity to specify their "ideal" ICT-based tool, from its functionalities to what it should look like, and asked to identify what might motivate them or restrict them from using the tool. This activity highlighted the differences between pilot buildings and different user groups. Residents had a preference for an alarm-based tool but were also keen on a design, which incorporated ideas such as a dashboard, an advisor and rewards. Facility managers within the residential buildings were keen on a feedback based tool which could be used to run the building more efficiently.

Within the non-residential buildings a range of preferences were uncovered. In the Health Care Centres (HCC) there was a preference for an energy dashboard and advisor which can display important information in an easy and understandable format, with additional functions including setting alarms and being able to set building controls such as thermostats. Similarly, in office buildings the idea of a dashboard, which could raise awareness and be linked to staff computers, was preferred, alongside functions such as alarms, energy advice, feedback, competitions and a communication loop to report issues. Within schools there was a desire for gamification elements to be included so that rewards and competitions could be supported in an attractive manner. A dashboard was preferred within schools with similar additional functions, including alarms and advice, which can support feedback on energy use, and which can be displayed on screens to inform students and staff.

BUILDING USER QUESTIONNAIRE

The questionnaire sought to identify the most common energy-related behaviours where respondents saw potential to make energy savings. Within residential properties the most prominent issues raised were lighting (100 %) and heating behaviours (86 %). In office buildings, use of additional heat sources (92 %), lighting (72 %) and computer use behaviours (68 %) ranked highest. In schools, computer use (87 %) and behaviours surrounding lighting (83 %) were highest ranked. In health centres, lighting (83 %) and additional heat source use (78 %) was the most prominent issues. This suggests that eTEACHER could usefully address each of these issues, and highlights common issues, such as inefficient lighting use, across several building types.

In terms of comfort-related behaviour, such as heating use, the opportunity for users will depend on their agency to control heating and cooling to achieve thermal comfort. A high proportion of users reported adjusting their thermal environment by opening and closing of windows or through the use of window blinds or shades. Across all responses 38 % of building users (11 % residential, 27 % non-residential users) indicated that they had no control over the thermal environment of the building. Those with little or no control often need to contact the energy manager or facility management teams to request that something is done to improve their comfort. Within the residential apartment blocks, users are indeed restricted as to the maximum temperature they can achieve in their own apartment, as the maximum set point is set by the facility management. Only 21 % of residential building users and 30 % of non-residential users said that they had reported an issue within their building relating to energy use and/or their own comfort. Reasons stated for this included not having enough time (11 %) and not knowing the relevant person to contact (7 %). Satisfaction with thermal comfort was generally high though, with only 5 % of residential users being dissatisfied and 21 % in non-residential buildings.

User awareness of energy use within the eTEACHER pilot buildings was fairly high. In residential buildings, 52 % reported being very aware and 5 % unaware; in non-residential buildings, awareness levels were lower (32 % very aware; 21 % unaware). There was general support however for saving energy – 82 % of those surveyed said this was very important, and 17 % somewhat important. Thus, the people that responded to the survey were a relatively supportive and energy-aware group. This support was reflected in 90 % of users expressing interest in knowing more about the energy used their building. The most strongly supported approaches for learning more were through data on total energy consumption and individual room temperatures, and receiving energy saving advice.

Users were asked how they could benefit from using the tool. The most important factors for users were: environmental impact, cost and personal comfort. Cost was of relatively high importance for residential users with 54 % selecting it as the most important factor for them.

Potential engagement with eTEACHER interventions was explored and most users (77 %) reported being likely or very likely to take part. In terms of how to promote eTEACHER, respondents most strongly supported posters around buildings, emails and announcements on TVs/screens. Users were asked what would most motivate their participation. Residential respondents highlighted monetary rewards (62 %), personalised energy use information (57 %) and having a significant environmental impact (55 %); non-residential building respondents indicated that they would be encouraged by making a significant environmental impact (66 %), personalised energy use information (63 %) and an improved image for the building (49 %). All respondents were interested in hearing ideas from others such as energy saving tips & advice and building improvement suggestions. This was the same kind of information that users were most happy to share with others from their own experiences. This suggests that there is the potential to develop "building communities" to further enhance engagement.

SITE VISITS

The site visits allowed for all building users and any influential middle actors to be identified, the agency of all actors, and the existing level of monitoring of energy and indoor environmental quality. It also allowed for building-specific challenges and opportunities towards improving energy efficiency and behaviour change to be identified. The site visits uncovered varying levels of agency within the buildings, given some are managed externally. The Health Centres in Spain are managed externally by the Regional Public Health Service, who instigate all general recommendations for similar buildings in the region. Any energy-related issues within the centres are dealt with by a public maintenance service, or private subcontractors for smaller maintenance issues. Therefore, the everyday Health Centre users do not have a significant impact on changing the energy services used. The Council House, UK, is managed externally by the City Council, so although there is an in-house facility team, the energy targets and strategy is determined externally. The Council House also has the additional complexity of being a Grade II listed heritage building and requires approval for any alterations to be made to the building fabric or appearance. This affects the monitoring equipment, which can be installed in this building. A summary of the site visit findings relating to existing monitoring data available, key challenges, opportunities and the views of the building users towards implementing an energy based ICT tool are detailed in Table 3.

As seen in Table 3 there is a great level of variation between the eTEACHER pilot buildings across all categories. Although eTEACHER is installing monitoring sensors into the buildings to send data to the developed tool, this does highlight the difficulty of trying to rollout a "one size fits all" tool without understanding the context of each building and its users.

Discussion & Conclusion

eTEACHER is based upon the principle that user engagement can enhance the design of an ICT-based tool, and that building communities of stakeholders is a desirable and effective approach. The results from the first year of eTEACHER have identified specific problems within each pilot building and the viability of certain solutions within each building, in particular, the differences between commercial and residential buildings. Although the project is still at an early stage, some initial observations can be made and are summarised below.

Firstly, constraints relating to the specific buildings highlight opportunities and limitations of an ICT-based tool for energy conservation. In short, substantial challenges exist around designing an app that can accommodate multiple building types, meter and data issues, alongside the variety of building users. These challenges highlighted the need for user engagement in these buildings to overcome them. Insights were gained around the potential for an ICT-based tool to empower users through addressing their needs, wants and beliefs. Many building users in the eTEACHER pilot buildings reported being restricted in altering their thermal environment, through tamper-proof thermostats and radiator valves to uncertainties in knowing who to contact and expressed the desire for an easier way to report issues. Here, an ICT tool which allows users to report issues and see updates on actions by the facility management could allow users to feel more empowered within the building and more satisfied with being able to instigate a change. Leaman (1995) found staff is often more 'forgiving' if they are at least informed of what is happening to improve the thermal environment. Therefore, for eTEACHER enhancing communication between users within buildings through the tool could result in improved user satisfaction within the building and enhanced engagement with the tool as it is benefiting the users' comfort. Improved satisfaction has been found to benefit workplace environments, given the correlation found by Oseland & Bartlett (1999) linking productivity with perceived control of environmental conditions as this could result in better productivity and job satisfaction, however there is a lack of evidence whether resident satisfaction is improved through enhanced communication with facility management within residential buildings.

Secondly, more nuanced views of feedback must be incorporated into the app design. This includes the technology to use, as whilst smartphones are nearly all pervasive, many users still may not have access to phones in their workplace or in schools. To overcome these variances the app needs to have customisable layers to enable individual choice and preference. Alongside this, is the need to create layers within the app, for example, the app may have main headlines, which could be expanded for more detail depending on the user's time and interest levels. In fact, this reflects the features of Jacucci et al.'s (2009) EnergyLife mobile app where numerous levels of detail were made accessible to the user. While details varied between groups in user workshops, the prevailing trend was to build in flexibility so that busy users would feel less pressure to devote their time, and therefore more inclined to engage regularly.

User feedback highlighted a desire for a simple, customisable and engaging tool that fits with the different interests and time constraints of user groups, as previous research has also highlighted. For example, Fitzpatrick and Smith (2009) noted a preference for at-a-glance information, while Hargreaves et al. (2010) reported that users can be put off by the need to actively engage. In the workplace environment, multiple studies highlight a perceived incapacity to pursue energy matters owing to higher priorities (e.g. Bull et al., 2015; Boomsma et al., 2016), a view which did come up in some of the user workshop sessions. The issue should not be taken lightly given that it may obstruct efficacy further down the line, as found by Van Dam et al. (2012) who noted that, after interest waned, complete abandonment of efforts might be triggered by minor technical issues. Users' time-poverty and/or impatience is reflected in the solutions proposed by studies such as Wilson et al. (2010) who recommend brief information bullets to maintain interest. Likewise, the MOBISTYLE project (Tisov et al., 2018) recommends "Calm Technology principles", so that interventions are clearly integrated with everyday activities and existing systems.

Finally, as with many research projects carried out in the real world, participation is a major challenge, especially over the long-term. The numbers attending are promising, as is the formation of feedback forums in each of the pilot buildings, but as the project develops, generating sustained engagement is a key priority. Promising approaches to achieve this include collective action and dialogue (Bull & Janda, 2018) and framing engagement around intrinsic motivations (e.g. for health, comfort, contribution to social good) (Crompton, 2008). Thus, a framing that emphasises comfort and acting together, combined with implementation that provokes engagement via gamification (e.g. completing challenges) and making any financial savings visible and linked to aspirations may prove effective. This principle of developing one or more messages can

Table 3. Summary of key insights, challenges and opportunities discovered in each pilot building.

eTEACHER pilot building	Monitoring data available	Opportunities identified	Challenges identified	Building user views
InCity, Romania	Whole building electricity consumption. District heating consumption of whole building. Gas consumption (back-up boilers). BEMS in place	Improve efficiency of dealing with residents' complaints or building issues – facility team currently use paper system.	No data available on heating settings or appliance use in individual apartments. Getting residents on board to participate.	Common complaint over thermal comfort – residents too hot or too cold due to extreme weather conditions experienced.
Villafranca, Spain	Whole building lighting, heating, ventilation and air conditioning (HVAC), chiller and appliance use data. BEMS in place	Often whole building HVAC left on when only emergency department operational. Lights often left on when not needed.	Thermostats located in hallways/ corridors outside relevant rooms, accessible to all building users. Heater directly above main entrance with automatic doors so large heat loss.	Thermal comfort common complaint – often users open windows whilst heating is on to improve comfort.
Guarena, Spain	Whole building lighting, HVAC and appliance use data. BEMS in place	Often whole building HVAC left on when only emergency department operational. Lights often left on when not needed.	Thermostats often not located in the locations they control. No in-house maintenance team – all external companies.	Thermal comfort a common complaint – staff ask reception for temperatures to be altered.
Torrente Ballester, Spain	Whole building electricity consumption via bill data.*	Lights often left on when not needed. Computers and overhead projectors left on when not needed.	Often difficult to control thermal environment in individual classrooms so windows opened when heating on. Students not allowed to use smartphones, limiting potential engagement.	Thermal comfort common complaint
Arco Iris, Spain	Whole building electricity consumption and oil consumption via bill data*	Lighting automatic (mornings) manual (afternoon) – often left on. Heating often left on when not needed.	No monitored data available. Staff is the only target group, as other users aged 3 years and under.	Only perceived way of reducing energy consumption is to replace existing appliances.
OAR, Spain	Whole building lighting, HVAC and appliance use data. BEMS in place.	Improving thermal comfort to reduce additional heat sources. Keen environmental motivation. BEMS use, as currently not known how to operate correctly.	Use of personal heaters. No set responsibility relating to control of BEMS – security switch system on in morning, cleaning crew switch off in evening. Thermostats locked in tamper proof casing so staff can't alter.	Many building users complaining about thermal environment in building – too hot/too cold.
Residential Block, Spain	Whole building electricity consumption. Heating consumption through third party.	Lights often left on. Areas of building heated when not needed. Residents admit to leaving some electrical appliances on.	No data available on heating settings or appliance use in individual apartments. Getting residents on board to participate.	Low response from building users to share views.
Council House, UK	Whole building electricity consumption. Whole building district heating consumption (however also includes adjacent unused building).	Lighting left on when not needed. Improving thermal comfort in building to reduce use of additional sources. Caretaker keen on energy efficiency but doesn't see any energy use data.	Building used for multiple purposes – council meetings, weddings, registrations, Coroner's meetings, private events. Listed building. Lighting controls often not in relevant locations. Staff often uses personal fans and heaters to improve comfort. Staff restricted from altering temperatures and tamper-proof radiator valves on some floors.	Thermal comfort and lighting levels a common complaint. Building fabric needs upgrade to make significant energy savings rather than users changing behaviour.
Djanogly, UK	Whole building electricity consumption. Whole building gas consumption.	Lights often left on when not needed. Computers and overhead projectors left on when not needed. Main hall often very cold but very expensive to light.	Facility crew currently checks all lights and appliances on room-by-room basis at end of each day. Students not allowed using smartphones, limiting potential engagement. Staff workloads will limit potential engagement. Valves on radiators tamper-proof so staff must request changes in valve position.	Thermal comfort a common complaint. Some staff could view intervention as "additional work".

**eTEACHER is adding smart meters in these buildings to ensure that the tool can receive relevant energy consumption data.*

be combined with choosing appropriate messengers, linking back to Robinson's (2011) Enabling Change step of identifying the "right inviter" to promote a project.

So, in conclusion, ICT-based behaviour change interventions hold promise in conserving energy and becoming embedded in a range of buildings but are likely to require sustained user engagement and acceptance to succeed. One of the largest challenges for eTEACHER is engaging all target user types, different building and types of agency. User engagement has already enhanced eTEACHER's design and sown seeds for a group of engaged stakeholders to provide further feedback. The challenge now is to embed this participation and develop a tool, which can prove effective at empowering users and saving energy across a range of building types.

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