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A LIVING LAB CO-CREATIONAL APPROACH TO ENERGY DEMAND REDUCTION IN NON-DOMESTIC BUILDINGS: UNDERSTANDING THE ORGANISATION

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Abstract

Public sector organisations are challenged by the Carbon Reduction Commitment (CRC) to contribute to an 80% reduction of carbon emissions by 2050. Due to the size of these organisations, even changes which are small in percentage terms can lead to significant energy savings. Energy efficiency and energy demand reduction are recognised by the Department of Energy and Climate Change (DECC) [1] to not only involve technological change, but also complex interrelations between the buildings, their systems and controls, and their users. In comparison to individual households, interactions in non-domestic buildings are complicated, due to the complex nature of the organisations that inhabit them. Three levels of analysis are evident in the context of organisations: i) institutional structures, rules, and policies; ii) the social and behavioural characteristics of the organisation; and iii) individual behaviours in the context of the organisation [2]. Changes in energy use can be enabled or hindered at each of these levels. This paper presents the current work of the Enhance research project, which takes a multidisciplinary approach to the study of energy use, and the potential for energy saving through smart digital feedback in two public sector organisations: a University, and a City Council in the UK. The project has a multidisciplinary team with expertise in data analytics, architecture and social sciences, enabling the study of complex interactions of infrastructure, organisations and users. The Enhance project is engaging in a living lab methodology to embrace its holistic approach to understanding energy use in the non-domestic buildings, and uses both quantitative and qualitative data gathering, analysis and feedback. We conclude that utilising the living lab methodology for exploring energy issues in large organisations involves gaining and understanding of formal and practical roles of individuals at multiple levels of the organisation, and flexibility in which roles and levels need to be involved in the living lab over time.

1. INTRODUCTION

Public sector organisations in the UK are challenged by the Carbon Reduction Commitment (CRC) to contribute to an 80% reduction of carbon emissions by 2050. Due to the size of these organisations, even changes which are small in percentage terms can lead to significant overall energy savings. Energy efficiency and energy demand reduction is recognized by UK Government DECC (Department of Energy and Climate Change) [1] as a problem not only of technological change but of complex interrelations between the buildings, their systems and controls, and their users. Non-domestic buildings contribute around 18% of total UK greenhouse emissions [3]. In non-domestic buildings, and by definition organisations, interactions are likely to be more complex than those of individual households. Three levels of organisation analysis are significant: i) institutional structures, rules and policies; ii) the social and behavioural characteristics of the organisation; and iii) the individual within their organisational context [2]. Changes in energy use are enabled or hindered at each of these levels. Further complexities are added when considering that public sector organisations such as universities sometimes operate as businesses, which produce as well as consume significant amounts of energy [2]. A number of barriers exist in an organisational situation that can hinder the effectiveness of interventions to reduce energy usage. These include lack of financial implications for those who use the buildings; sharing of work appliances, which can impact on an individual's sense of their capacity to affect energy consumption; and lack of effective feedback on the effect of their personal actions [4,5]. Understanding organisational issues through the hierarchy of the organisations and the stakeholders and users of the buildings is essential when developing organisational-wide interventions [2,6].

This paper presents the developing work of Enhance, an EPSRC funded non-domestic energy demand transformation project. The Enhance project is working with two public organisations situated in the UK: a City Council; and a University. Both of these organisations are large public sector bodies, each with significant energy use and with wider reach, whether in relation to local populations or higher education and knowledge. Both have a public requirements and legislative duties to contribute to the mitigation of climate change, as well as plans to reduce the size of their spending on energy. These complex organisations face the challenges, to achieve understanding and reduction in energy use. Both organisations are part of an evolving city wide Living Lab partnership.

Living labs offer a valuable approach with which to understand the complexity of the organisation, and develop innovation through social interactions with technology. Participants are drawn from within the organisation and are at the centre of the innovation, in real-life experimentation environments. This user-centred approach, involving co-creation and co-design, matches the opportunities offered by new ICT concepts and solutions to the specific needs and aspirations of local contexts, cultures, and creativity potentials [7]. These are based on human interactions with digital energy data and the design of technological interventions [8]. These interventions will be developed and tested in the living lab over a full year, with the aim of establishing methods for engaging organisations in effective energy awareness and reduction activities. The paper reports on the first phase of this process, which involves understanding the organisations' structures, policies and infrastructures relating to energy use.

2. UNDERSTANDING PUBLIC SECTOR ORGANISATIONS AND ENERGY

Social responsibility and sustainability are currently regarded as corporate requirements, particularly in the public sector. Public sector organisations also typically have public duties to contribute to energy and carbon saving targets. However, sustainability and energy are not the result of distinct activities or building infrastructure, but are the result of the actions and behaviours of all users of the organisations, be it the providers or the customers. Sustainability and energy use in buildings can be considered from the perspective of the building and its energy infrastructure, as well as the behaviours of the users. Though heavily intertwined, these perspectives are often considered as two separate entities. This results in buildings that are modelled to be energy efficient but which do not perform as expected once commissioned and occupied [9]. The separation between building and behaviour continues over time. In many organisations, energy management and control are dealt with separately to sustainability and energy reduction within the organisational structure. For example, Estates departments may have responsibility for buildings, infrastructure, and efficient running of the building management systems; whilst other departments, coming under a variety of guises (e.g. Sustainability, Social responsibility, Carbon Reduction, Energy), are charged with the responsibility for running programmes and campaigns to reduce energy use. This division of responsibility is reflected in the orgainisational structure of the two public sector organisations engaging in the Enhance project.

3. LIVING LAB CO-CREATIONAL APPROACH TO ENERGY DEMAND REDUCTION

At its core, the ethos behind the living lab approach is to take the traditional concept of the laboratory – as a facility for experimentation and knowledge generation - and open it up to the real-world, where research and innovation processes can be facilitated and informed by the sustained involvement and co-operation of relevant parties (e.g. users, companies, and public bodies) in familiar and every-day contexts [10-12]. It has been suggested that five key principles of the living lab approach are **continuity**, **openness**, **realism**, **empowerment of users,** and **spontaneity** [13].

References to living labs in the context of human-centered research and design first appear in the literature around the turn of the millennium [14-16]. Early living labs were often actualised as *simulations* of real-world settings. For example, Abowd describes the use of a purpose-built home as a ‘prototype environment’ for the investigation of emerging technologies [17]. Whilst many contemporary living labs still adopt this somewhat artificial, approach, there are also numerous examples of living lab projects that are deployed within existing spaces. Indeed, there is no requirement for living labs to be spatially delimited; they can involve both physical and virtual spaces, distributed across complex organisational structures. Furthermore, recent years have witnessed the growth of international networks of living labs, enabling widespread collaboration and the pooling of knowledge and resources [10,18]. These networks have bolstered the profile of living labs as a valuable approach to innovation[9,16].

3.1. Strategies for linking people and energy

The application of living labs to challenges surrounding sustainability has garnered particular attention [19]. This can be partially attributed to the fact that numerous authors highlight the need to incorporate detailed understandings of individual and organisational behaviours into the design and development of sustainable innovations [20]–[22]. Additionally, Voytenko et al. [19] point out that addressing sustainability challenges at local or district level enables the identification and empowerment of discrete sets of actors who are able to monitor the effects of their actions and address specific challenges. The living lab concept appears to be well suited to addressing these issues.

A central component of living labs is the involvement and collaboration of diverse groups of stakeholders. It is important to consider the management of relationships, roles, and motivations over the course of a living lab project. Juujarvi et al. [25] point out that power struggles and poor cooperation skills are barriers to collaboration in living labs, and that for successful interaction, participants first need to learn to interact with one-another. They suggest that living labs should combine bottom-up and top-down management approaches. The former is well suited early on in a project, during brain-storming and needs generation; whereas, the latter is required to validate concepts and ideas, and provide formal structure. Hyysalo and Hakkarainen [26] discuss the importance of reconciling different interests of participants, and recommend retaining an open agreement of what the outcomes of the collaboration could be, whilst also ensuring all parties are realistically informed about uncertainties and development needs in relation to technology and user practices. Finally, with respect to motivation, the incentives for living lab participation are likely to be varied and role-dependent. In general, Baccarne et al. [27] suggest that motivators tend to be intrinsic (e.g. personal interest, problem solving, and developing collaborations), but that for repeated participation, material incentives gain importance. Georges et al. [28] highlight the importance of communication with test users in minimising drop-out attrition during living lab field trials.

3.2. Challenges of Living Lab Methodology

Despite more than a decade of work, there is a lack of consensus regarding methods for conducting living lab research. Instead, methods are often adopted, modified, and combined from associated disciplines, such as ethnography, action research, social practice theory, human-computer interaction, and open innovation. These methods include analysis of automatically collected data (e.g. system logs), questionnaires, focus groups, and observations [12]. Pierson and Lievens describe four stages of the living lab research cycle: i) contextualisation, ii) concretisation, iii) implementation, and iv) feedback [23]. *Contextualisation* is an explorative phase, which is initially used to establish the necessary background and insights required to define the research framework and identify eligible participants. Subsequently, *concretisation* involves establishing a thorough description of the existing characteristics, behaviours and opinions of the living lab participants with respect to the research focus. *Implementation* refers to the operational testing phase, where the innovation (technology or service) is deployed, and data are gathered and processed in

relation to its adoption, meaning, motivations and influence. Finally, the *feedback* phase takes place at the end of the project, and involves the analysis of perceptions, attitudes, and usage of the innovation over time. This phase should also generate technological recommendations, based upon the analysis of data collected during the implementation phase. Comparable three phase models of living lab research are proposed elsewhere in the literature, consisting of insight research/needs generation, prototyping/design, and field testing/evaluation [24] [10]. The lack of well-defined living lab methodologies means that practitioners make use of existing guidelines and literature in order to select and adapt methods to suit the aims and context of their project.

4. ENHANCE LIVING LAB

The Enhance research project takes a multidisciplinary approach to the study of energy use, and the potential for energy saving through smart digital feedback, in two public sector organisations, that of a University and a City Council. Recognising the complex interactions of infrastructure, organisations and users, the project multidisciplinary team, have backgrounds in data analytics, architecture and social sciences. The project is engaging in a living lab methodology to embrace its holistic approach to understanding energy use in the non-domestic buildings, and uses both quantitative and qualitative data gathering, analysis and feedback. The living lab methodology enables an in-depth immersive experience whilst engaging with building managers and building users about energy in the environments in which they perform their daily work and activities within the buildings. Understanding the effects of organisational behaviour on energy use is a key part of the research, and this paper presents the relevant insights from the organisational perspective following engagement with top and middle management.

4.1 Enhance Methodology

Living labs by their very nature entail research in the real world. The researcher enters in to the world of their participants. Recruiting participation for the living lab has involved access to senior management of the organisations for entry into the worlds of the potential participant; negotiating buy-in and permissions through the management hierarchy. The Enhance methodology involves understanding large complex public organisations and developing ways for users to interact more effectively with energy use. The methodology is based on selecting appropriate and relevant contexts for the living lab that represent aspects of the larger organisation and offer opportunities for engaging communities of building users.

In the Enhance project, understanding organisational objectives, management roles, structures and policies are an essential part of understanding the restraints, demands and areas of discretion over energy use, right from top management to the floor-level and pubic users of the building. Hence all the meetings, negotiations and interactions are elements of the living lab. At the same time, they are part of the pathway to negotiating

Time	Activity	Personnel Resources
30-60 minute	Interviews: To gain understanding of: the organisation, and the impacts of its political, managerial and budgetary responsibilities on energy demand	Senior management, Facilities management and a sample of all types of building users
10-15 minute x2	Online and or paper survey. To evaluate views and social norms towards energy use. Pre and Post Living Lab	All users of the building,
60 minutes every 3 months over period of 1 year	Project Board Meetings, to keep senior managers informed of status of project	Senior Management
30 - 60 minute every 6 to 8 Weeks	Meeting with Line management within Living Lab to enable two way feedback between project and line management to ensure meeting targets for both groups	Living Lab line management Steering Group – line managers in building engaged in living lab
60 minutes Every 6 weeks	Co-creation, co-design, review and development meetings with subgroup of living lab participants	Users who have volunteered to engage in the project, may include, office staff, hot desking staff, catering staff, cleaners, and public users.
1 to 5 min daily interaction with the intervention	Interaction with the digital information with regards to energy use. What this will be will depend on the Living Lab co-creation and co-design of the building users.	All living lab participants

Table 1: Planned Living Lab Activities

researcher access to the organisations, and to particular buildings, and part of the co-creation and co-design of the digital innovative living lab with the users. The level at which the co-creational living lab sits within the organisation will indeed be determined by these negotiations and the identification by the people in and of the building. The living lab could involve top management, middle management, the user at their desk, the public users of the building, the facilities managers, estates workers, or security personnel; and most likely a combination. The very nature of the living lab means the researcher is entering in to the real world of the workplace/building as negotiated and defined by the process, without preconceptions of where the co-design living lab will be. The focus of the participants is their work and the activities they must carry out in their

daily routines and work responsibilities; the researcher has to engage the participants whilst at the same time minimalizing as far as possible the impact on the participants usual role. Two vital aspects shape the process. If the living lab has too high a time or person cost on the user, then they may withdraw their participation; co-designed interactions must not interfere with the requirements of workplace requirements.
The start of the Enhance living lab journey began with the initial buy in from the two organisations before external funding was sought for the project – this was an agreement in principle to participate in the project from the Heads of energy- and sustainability-related departments. Once EPSRC funding was awarded and the project underway, the detailed engagement and buy in process began. To date eight meetings over a period of four months with the senior management have taken place (see Table 1 for the list of planned living lab activities). The nature of the meetings were to gain mutual understanding between the parties with regards to aims of the project, how these fitted with the aims and drivers for the organisations, identification of buildings and opening pathways to managers in those buildings and departments. Identifying and engaging the support of heads of departments will be required in gaining access to data and information flows, Building Management Systems (BMS), *etc*. The next stage of negotiation is to gain access to the buildings identified by management, to evaluate the suitability of the buildings and building user type, the engagement of the occupants of the building as participants to the living lab.

3.3. Detailed Selection of Buildings for Living Labs

Both organisations have large complex estates with widely ranging building stock and use. In age, the building stock ranges from 16th century to current new builds. Large organisations are constantly in process of development and both organisations have ongoing new build programmes. This wide range in age of buildings also meant the infrastructure and systems operating within the buildings also varies greatly from modern systems to older systems, some with and some without upgrades. From an energy perspective the upgrading of infrastructure to implement energy saving measures may also be affected by requirements to meet architectural or other cultural conservation measures. The use of the buildings includes provision of accommodation, residential care homes, teaching spaces, laboratories, libraries, office spaces, and schools, amongst others. Redevelopment and reorganisation of the estates also meant that departments may be planned to move from the buildings, there may be planned change of use, and planned relocation of some or all of the building users. Both organisations are also engaging in energy reduction programmes via both behavioural and infrastructure change. All of these listed factors need to be taken into account when identifying the building selection for study. Table 2 provides a list of the ideal criteria to be met for any buildings to be selected for participation in the living lab.

Feature	Criteria
Facilities Management:	Run by the organisation
Infrastructure:	No planned major infrastructure changes either to the building or to users or services or organisational change.
Value to organisation:	A building which meets with the desires or needs of the organisation in terms of and identified need or area of concern, or complimentary to work they are already doing or would like to do.
Billing:	Ideally - localised accountability for utility billing, but not essential
Metering:	Ideally - Localised metering: Metering in units of the building e.g.: different areas, floors.
Minimum metering	Building level metering
Building Management System (BMS):	Has a BMS system; - Recent within the last 10- 12 years, preferable new within 3-4 years
Data Out of System:	Ability to get data out of BMS to Enhance database
Information to users:	With negotiation with IY departments. • Ability to send a prompt to users to look at feedback either via pop up on desk top, or email, or text to mobile phone. • Where there are plasma screens ability to place information on then and or the ability to install our own plasma screens. • Where there are work mobile phones ability to download an app designed by us.
Information from users:	Ability for users feedback to be sent to Enhance servers
Sensors:	Possibility to install Enhance sensors if required and ability to send data via, network back to Enhance servers. For example: CT clamps, temperature, humidity, motion,
Age:	Not under 1 year i.e. passed snagging period
Facilities Management	A building where the facilities management feel the setup is correct but it's how the building is used that's preventing good environment and energy saving
Users:	• A building where there is some degree of freedom/control or opportunity that the users can make changes in behaviour to make savings or increase environmental satisfaction. • Where people are engaged and willing to take part. • Where there are interesting organisational dynamics impacting on energy use

Table 2: Ideal Criteria for Building Selection

5. PRELIMNARY FINDINGS

Over the course of our initial meetings with stakeholders at the local Council and University sites, we have identified preliminary findings that are of potential value, and that could influence our on-going work. These are briefly detailed below.

5.1. Complex and poorly-defined roles

It is clear that the structures of our selected organisations comprise complex and, in some cases, overlapping roles regarding the control and management of energy usage and sustainability issues. We interviewed a facilities manager who was responsible for 25 buildings within the organisation, whilst other organisational premises were found to have dedicated facilities managers. In addition to a facilities manager, one site also had a 'building manager', and it was apparent that there was a lack of differentiation between these roles with regards to building related issues. In general, it is clear that people's job titles alone do not provide a clear indication of their roles within the organisation. Responsibilities appeared to be assigned and negotiated in response to individual factors, such as a person's familiarity with the site and their day-to-day interactions with other staff members.

5.2. Disjointed energy control and management

With regard to decision-making and control over energy related issues, we identified complex and disjointed organisational arrangements. For example, in both Council and University sites the energy bills for the buildings were usually but not in all cases covered by central costs, and the building/facilities managers often lacked detailed information about actual energy consumption or costs in their buildings. The level of control that the building managers had over their buildings was also very variable and generally quite limited. Despite the presence of a BMS in one of the council premises, all management of this was carried out remotely by an external company. A BMS display screen in the plant room provided detailed graphs of energy use and temperatures across different zones of the building, however, the building manager was unaware of this information. The only control that the building manager had over the system were local thermostats, spaced roughly 10 metres apart around the building; which comprised office space, a public library and meeting areas. These thermostats were also frequently adjusted by building users, who were also able to adjust the thermal environment by opening and closing windows and vents. In order to make any adjustments, for example; to the heating set points , on and off times, zoning and lighting levels in the building, the building manager would have to call the building management company and request for changes to be made. A similar situation existed at one of the university sites, where requests for changes to the building management system were made to the estates department. Furthermore, in both sites the building managers stated that the occupants/users of the building had expectations that the building manager had control over the systems. In neither case did there appear to be any responsibilities to ensure minimal use or energy reduction practices by the building manager, however, it was something they were aware of and talked about wanting to be able to have an impact upon.

5.3 Conclusion

We conclude that utilising the living lab methodology for exploring energy issues in large organisations involves gaining and understanding of formal and practical roles of individuals at multiple levels of the organisation, and flexibility in which roles and levels need to be involved in the living lab over time. In practice, roles can be complex, poorly defined, and often do not correspond closely to formal descriptionsm, and the fact that energy is central to many aspects of the organisation – finance, operations, quality – means that responsibility for energy is often spread across multiple organisation units.

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