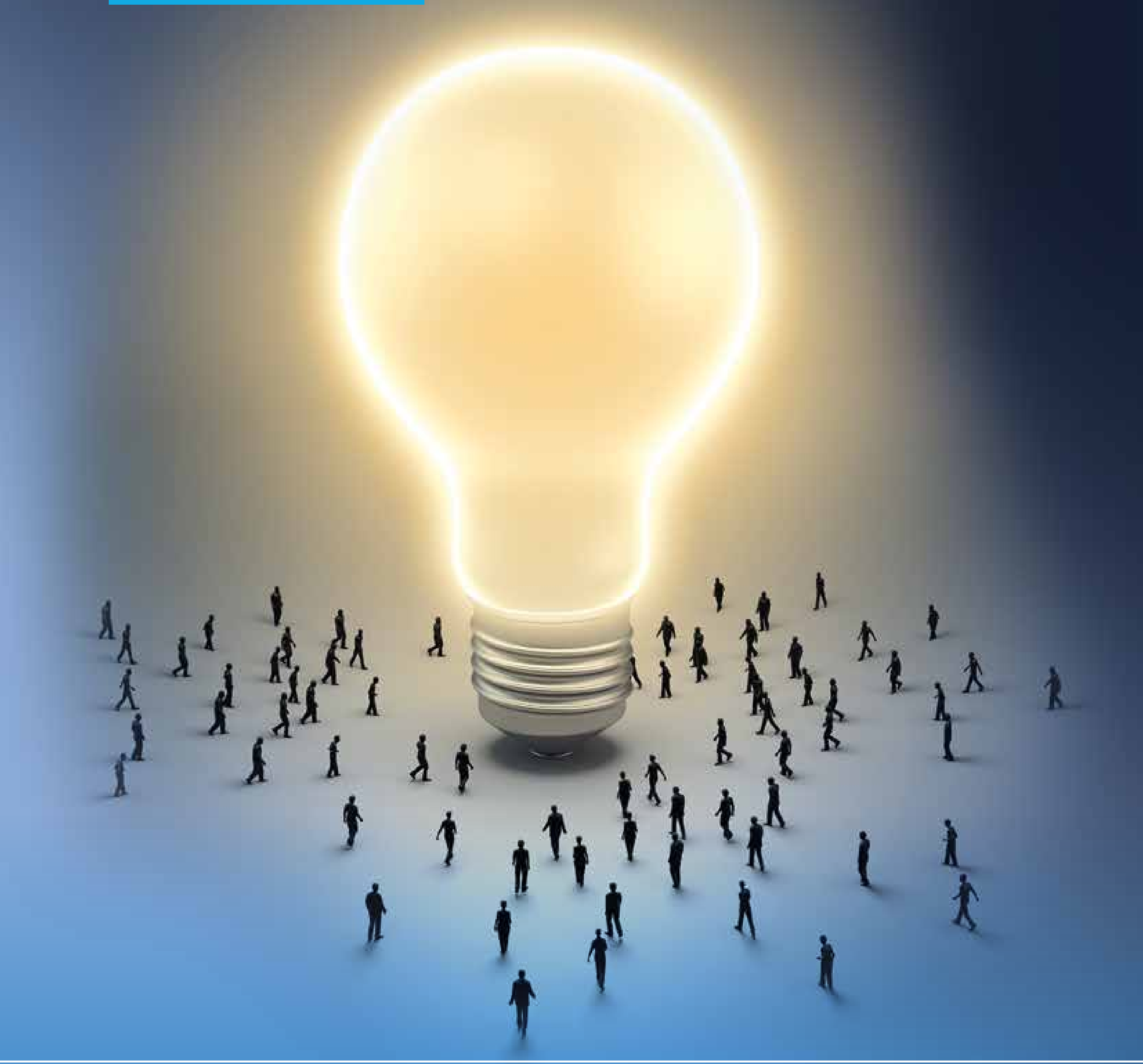
C-tech: Creating the Energy for Change Final Report

June 2017



Alexa Spence, Enrico Costanza, Nick Banks, Murray Goulden, Ben Bedwell, Caroline Leygue, Rayoung Yang, Derek McAuley

This report should be cited as: Spence, A., Costanza, E., Banks, N., Goulden, M., Bedwell, B., Leygue, C., Yang, R., McAuley, D. (2017). C-tech: Creating the Energy for Change Final Report. University of Nottingham: UK.

This research was developed and carried out in partnership between Horizon Digital Economy Research at the University of Nottingham, Electronics and Computer Science at Southampton University, University College London Interaction Centre (UCLIC) and the Centre for Sustainable Energy (CSE).

Horizon Digital Economy Research

Established in 2009 and centred at the University of Nottingham, the RCUK-funded Horizon Digital Economy Research Hub and Centre for Doctoral Training brought together a team with expertise spanning a wide variety of disciplines to address challenges in the Digital Economy. In partnership with academic colleagues from the Universities of Cambridge, Exeter and Strathclyde, and the Royal College of Art, we research 'in the wild', embedding our research in the practices of our external partners spread across a wide range of business sectors.

Southampton University

Electronics and Computer Science (ECS) is the leading university department of its kind in the UK, with an international reputation for world-leading research across computer science, electronics, and electrical engineering. Research takes place in a multidisciplinary, collaborative environment and draws on our outstanding facilities. With over 550 researchers from many different subject backgrounds, the research culture in ECS is fast-changing and dynamic.

University College London Interaction Centre

UCLIC is a world leading Centre of Excellence in Human-Computer Interaction teaching and research, studying interactions between people and technology, drawing on the best scientific traditions in Computer Science and Human Sciences, and working collaboratively with the research community and industry.

Centre for Sustainable Energy

The Centre for Sustainable Energy (CSE) is an independent national UK charity working to tackle the threat of climate change and to end the misery of cold homes. Established in 1979, CSE has a national reputation for excellence in fuel poverty research, energy policy analysis and community engagement in sustainable energy. Our cross-disciplinary team combines research, technical analysis, community engagement, insulation scheme management and home energy advice.

Contact details:

Alexa Spence

School of Psychology,
University Park,
University of Nottingham,
Nottingham, NG72RD

E: **alexa.spence@nottingham.ac.uk**
W: **www.energyforchange.ac.uk**

Acknowledgements

This research was funded by the Research Councils UK Digital Economy Theme (Ref: EP/K002589/1) and received additional support from Horizon Digital Economy Research (Refs: EP/G065802/1 and EP/MO2315X/1).

The authors would like to thank the other team members, specifically James Colley, Mike Jewell, and Rupert Meese who contributed extensively to the work described here. We'd like to thank the members of the advisory panel for providing insight, discussion and strategic direction including Michael Harrison (BEIS), Mike Summers (Arup), Neil Merrall (Siemens), Tom Hargreaves (UEA), Joseph Williams (UK Green Building Council), Mark Conner (University of Leeds), Jacky Pett, Simon Roberts (CSE), Mike Hazas (Lancaster University), Chris Large (Global Action Plan), Gunnar Stevens (University of Siegen), Frances Bowen (Bath University), and Chris Jones (Sheffield University).

We also thank the Transforming Energy Demand through Digital Innovation network (TEDDInet) for their extensive support of our project and other similar projects within this field. In particular Sam Staddon, Cat Magill, and Dan van der Horst for creating opportunities for discussion and engagement as well as providing their own perspectives.

In addition, we acknowledge the time and efforts of our partner sites who allowed us to trial communications and interventions in their places of work. Without this support and engagement this research could not have been conducted.

Thank you to those who provided feedback on earlier versions of this report, in particular Chris Jones.

Project Team

Alexa Spence is an associate professor at the University of Nottingham and has expertise in researching public perceptions and behaviour, particularly relating to energy and climate change. She previously held postdoctoral positions at the University of Nottingham and Cardiff University before returning to Nottingham in 2010. She leads the energy team at Horizon and is the principal investigator of the Ctech project.

Ben Bedwell is a research fellow at the University of Nottingham where he conducts applied research and development with Horizon Digital Economy Research Institute and the Mixed Reality Laboratory. He is interested in the ways that end-users understand and interact with novel technologies, particularly when the technologies are used to engage visitors with cultural and environmental sustainability.

Enrico Costanza is a lecturer in Human-Computer Interaction at the UCL Interaction Centre. His research lies at the intersection of design and technology and it is influenced by behavioural and social sciences. His current focus is on designing systems that can help people make sense of data (e.g. from the Internet of Things or from Energy Smart Meters) and on interaction with smart and autonomous systems in everyday situations.

Caroline Leygue is a research fellow in the School of Psychology at the University of Nottingham (UK). Her area of expertise is the study of social and environmental behaviour, and in particular automatic and controlled processes. After studies in France and Canada, she did her PhD in Paris and held postdocs in the UK. Her academic work includes posts at the INSEAD Business School, Cardiff University and the University of Nottingham.

Murray Goulden is a senior research fellow at Horizon Digital Economy Research with a background in sociology and science and technology studies. His work focuses on the role of digital technologies in social practices: on the changing patterns of life that result, and the implications for governance, specifically in the areas of energy, digital data and everyday life.

Nick Banks is a social researcher at CSE specialising in social dimensions of energy consumption but has also served his time working on more technical projects including energy and environmental audits and implementation of environmental management systems. Most recently he has been involved in a number of projects which explore organisational decision making with respect to energy efficiency and environmental issues.

Rayoung Yang is a post-doctoral researcher at the UCL Interaction Centre. She received her Ph.D. in Information and a MS in Information at the University of Michigan. Her research interests are in the areas of Human-Computer Interaction and Ubiquitous Computing, with a focus on support for design and evaluation of novel applications and technologies with the goal of saving energy.

Eamonn Ferguson is professor of health psychology at the University of Nottingham. His current theoretical work focuses on the integration of theory and models from psychology, in particular personality theory, with behavioural economics, to address questions focusing on (i) the overlap of personality and pro-social preferences, (ii) understanding blood and organ donor behaviour, (iii) resource allocation and, (iv) subjective wellbeing and emotion processing.

Derek McAuley is professor of Digital Economy and Director of the Horizon Digital Economy Research Institute at the University of Nottingham. His computing research interests span ubiquitous computing, computer architecture, networking, distributed systems and operating systems, while his interdisciplinary interests include issues of ethics, identity, privacy, information policy, legislation and economics within a digital society.

Table of Contents

Executive Summary

Workplaces are interesting spaces in which people consume energy. These are often communal and the people who use energy often do not receive feedback on their usage or need to pay for what they use. Motivations for using and reducing energy are therefore quite different to a residential context on which much of the previous research base focuses. Notably, workplaces are also responsible for a huge amount of energy consumption and therefore have great potential to reduce energy consumption and related carbon emissions. With attempts to reduce workplace energy use often focused on intelligent building services and design, the occupants of the space can be overlooked. Building users have direct control over much of the office equipment and lighting which regularly accounts for more than half of overall energy consumption in commercial buildings1, and considerable influence over major uses of energy, heating particularly. User behaviour has then an important impact on workplace energy use[2].

This report is the culmination of a large multidisciplinary programme of research that explored interactive shared energy feedback and building user engagement in the workplace. The project developed distinct streams of research around exploring energy in the workplace context, how people use and interact around energy, the technicalities of energy monitoring, and developing digital interventions for energy visualisation and engagement. These research streams fed into the development of an energy management toolkit for the workplace featuring energy engagement software known as e-Genie. We have undertaken an in-depth exploration of multi-occupancy workplace buildings with an extensive set of studies and deployments which have provided us with good insights into energy perceptions, engagement, and management and the potential for digital tools in this space, see Figure 1.

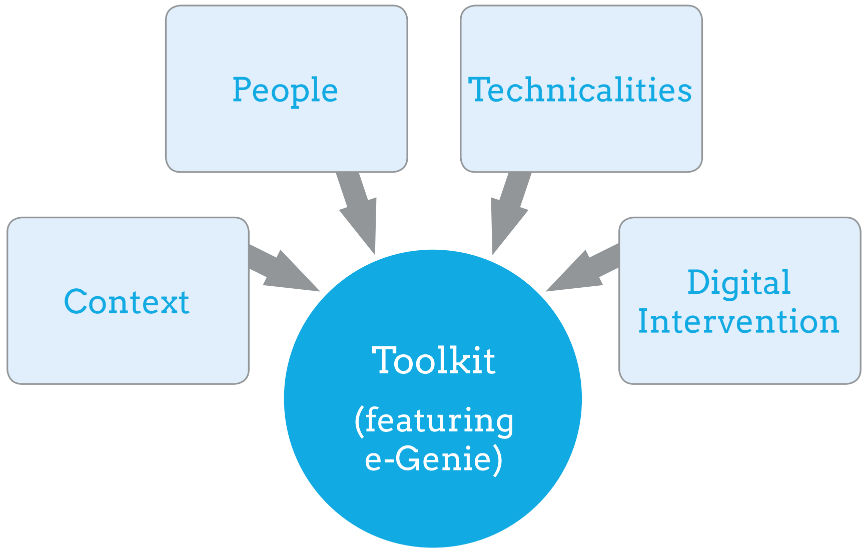


Figure 1. Illustration of how different research streams within C-tech, led to the development of an Energy management toolkit for the workplace.

[1] Murakami, S., M. D. Levine, H. Yoshino, T. Inoue, T. Ikaga, Y. Shimoda, S. Miura, T. Sera, M. Nishio, Y. Sakamoto, and W. Fujisaki. 2006. Energy Consumption, Efficiency, Conservation and Greenhouse Gas Mitigation in Japan's Building Sector. Lawrence Berkely National Laboratory.
[2] IPCC (Intergovernmental Panel on Climate Change). 2014. "Climate Change 2014: Mitigation of Climate Change." In Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

We conclude that **communication is a key element of energy management** that is often overlooked and supporting communications between energy managers and building users can be an immediate way of gaining energy efficiencies and savings. Facilities management is frequently characterised by an absence of engagement with building users and building users often have limited direct control over local energy use but importantly are a key source of information about energy use. Notably, **organisational processes, goals and leadership matters**, and this will affect motivations driving energy saving behaviour. We observed that energy technology installations can be a way of signalling leadership and influencing the organisational culture, and to be successful technological interventions must be supported by policy and integrated into current processes and structures. The amount of energy data available in workplace buildings is increasing all the time but we observe that **we need more understanding of energy data, not more data**; feedback visualisations can play an important role here in focusing attention on key information. We note that technological interventions must have a clear purpose and use case in order to be engaged with by building users and accepted. Importantly, in order to continue engaging users, **technological interventions should be dynamic and supported over time**; the linking in of this to current organisational processes and structures should ensure that the focus can be adapted to the evolving workplace needs.

Background

Non-domestic buildings currently account for around 20% of global carbon emissions[3]; figures which are set to increase in the future, making workplaces an important focus for energy efficiency and energy saving initiatives around the world. Various mechanisms exist to promote energy reductions in non-domestic settings, from voluntary agreements, adoption of Building Energy Management Systems (BEMS), energy audits, use of energy efficient technologies, and occupant engagement[4]. CTECH focuses on the latter of these options, namely interventions in the workplace which aim to change employee behaviour and by doing so, save energy. Literature on this subject is sparse, though that is now beginning to change, not least through the work of TEDDINET (Transforming Energy Demand through Digital Innovation NETwork[5]) projects.

The management of energy consumption within workplaces is not only significant at a national scale in terms of carbon emissions and energy demand, but also at the sites themselves, in terms of costs to the organisation and the influence on employee wellbeing of energy-dependant services such as heating and ventilation. Workplace contexts for energy use differ from domestic settings in a number of ways. The cost of energy use in the workplace may be of little relevance to most employees, whilst the sharing of facilities and appliances may create barriers to, or opportunities for, behaviour change[6]. Employees can be a captive audience and are subject to organisational policies, whilst the influence of social and group norms and sense of community may increase motivations to save energy in the workplace. Common to many workplace settings is the relevance of group dynamics and interactions between building users on energy saving[7], however we note that variation in terms of industry size and sector also affect the potential for savings.

As part of CTECH research, we conducted a systematic review of existing literature on energy behaviour change in the workplace[8]. We discovered a limited literature with only 16 previous empirical studies having examined the impact of energy interventions in workplace sites, indicating the need for further research in this area.

Drawing on the structure of Michie et al's[9] Behaviour Change Wheel, the review identified enablement (providing autonomy and support to employees), modelling (various forms of social influence) and environmental restructuring (changing the physical or social context) as key features of previously successful interventions to save energy in workplace buildings.

[3] IPCC (2014) IPCC AR5 Climate Change: Implications for Buildings Key Findings From the Intergovernmental Panel on Climate Change Fifth Assessment Report. Available at: http://bpie.eu/publication/climate-change-implicationsfor-buildings/.
[4] DECC (2012). What Are the Factors Influencing Energy Behaviours and Decision-making in the Non-domestic Sector. A Rapid Evidence Assessment, Centre for Sustainable Energy (CSE) and the Environmental Change Institute, University of Oxford (ECI0.
[5] https://teddinet.org
[6] Bedwell, B. Leygue, C., Goulden, M.,. Mcauley, D. Colley, J., Ferguson, E., Banks, N., Spence, A. (2014) Apportioning energy consumption in the workplace: a review of issues in using metering data to motivate staff to save energy, Technol. Anal. Strategic Manag. 26: 1196–1211
[7] Deline, M. B. (2015). Energizing organizational research: advancing the energy field with group concepts and theories, Energy Research & Social Science, 8. 207–221.
[8] Staddon, S.C., Cycil, C., Goulden, M., Leygue, C., Spence, A. (2016) Intervening to change behaviour and save energy in the workplace: A systematic review of available evidence. Energy Research & Social Science, 17: 30-51.

Examples of enablement included changes to organisational processes such as altering after-hours working practices by supporting and incentivising employees' moves to one particular location in the building, so as to reduce energy consumption in other parts. Modelling focused on social interactions, and often involved fostering comparison or competition between colleagues, either individually or in groups, or gaming amongst them. Environmental restructuring primarily included physical interventions, such as providing an online dashboards to provide real-time energy use feedback. This review indicates that energy savings in the workplace depend not only on the actions of building users, but also on the attitude and engagement of management, on wider organisational change and on investment in energy efficient technology.

We explored in more detail aspects of potential digital energy interventions in a review considering the potential for apportioning energy use within the workplace[9]. It is becoming increasingly possible to collect fine-grained energy data in the workplace. We find that disaggregation of energy data is increasingly possible and that apportionment of energy to groups that are spatially organised is preferable, rather than to transient communities or individuals, given both technical and motivational considerations. Again, a key aspect highlighted for new and developing energy policies is that these must be well integrated within, and coherent with, wider organisational policies. In particular, setting clear specific goals around energy use is likely to be effective, and even more so if feedback on these goals is provided. The review caveats the promise of apportionment by drawing attention to the social and ethical sensitivities around the monitoring aspects of this approach, as well as the need for better understanding of the motivational and social processes surrounding engaging workplace staff with energy data.

Relevant Outputs

Bedwell, B., Leygue, C., Goulden, M., McAuley, D., Colley, J., Ferguson, E., Banks, N. and Spence, A., (2014). Apportioning energy consumption in the workplace: a review of issues in using metering data to motivate staff to save energy. Technology Analysis & Strategic Management. Special Issue of Smart Metering Technology & Society. 1196-1211.

Staddon, S., Cycil, C., Goulden, M., Leygue, C. and Spence, A. (2016). Intervening to Change Behaviour and Save Energy in the Workplace: A Systematic Review of Available Evidence. Energy Research and Social Science. 17, 30-51.

[9] Michie, S. F., Atkins, L., West, R. (2014). The Behaviour Change Wheel: A Guide to Designing Interventions, 1st ed., Silverback Publishing.

Energy in the workplace context

1

Energy in the workplace context

We undertook extensive ethnographic work so as to generate a rich understanding of the practices involved in the day-to-day management of energy in the offices, including the key organisational roles and structures, the rationales at play, and the technologies involved. A grounded theory (data-led) approach to understanding energy use characterised the fieldwork. During subsequent analysis a social practice lens was also adopted in order to anchor findings in a deeper context. The outputs from this work informed the broad design of interventions carried out during the Ctech project, as well as ensuring each deployment was sensitive to the specifics of the site. Our analyses demonstrate that there is clear potential to better harness the vast amounts of energy data that are increasingly available to organisations and that energy management must be dynamic in order to keep up with changes with energy use needs.

The ethnographic fieldwork consisted of observations of key actors in the workplace including those involved in energy management, senior managers, and other office users. Observations usually lasted for a period of two to three days, and were supplemented with semi-structured interviews with these actors. During technical deployments, ethnographic work was also used to gather data on, and evaluate, the deployments (alongside survey work and workshops).

We established that the key roles in regards to everyday energy management were Facilities Management (FM) and Energy Management (EM). The terminology and responsibilities of these roles varied somewhat between organisation, and in some cases – specifically the SMEs – the latter role was often subsumed within the former and usually afforded little attention. The FM role consists primarily of ensuring the ongoing functioning of the infrastructure sustaining the doing of work. This included maintaining the integrity of the building and the equipment inside it. Particularly relevant to energy was the FM's control of the Building Energy Management System (BEMS), through which environmental factors such as heating, ventilation, and lighting are controlled. This role is primarily reactive, focused on 'keeping things going' by responding to problems as they emerge.

The EM role is by contrast far more proactive, centred on identifying opportunities to optimise the organisation's use of energy, and meeting the reporting functions required of the organisation by legislation, such as the Carbon Reduction Commitment (CRC). This role is usually one of data, rather than infrastructure, management. As a result, the EM has little or no direct access to energy management controls, and is required instead to work through others where changes are desired – primarily the FM.

Partner sites

Partner sites studied were all office buildings, and included two SMEs – a creative industries 'incubator' in which multiple start ups were housed, and a medium-sized tech company; two county councils; and two large enterprises, one an engineering firm and the other finance. At the councils, data was also collected on the work of managing energy at other diverse sites across the council's portfolio, including those now separated from the council, such as schools and leisure centres, which nevertheless continued to work with the council on energy issues such as billing and procurement.

Findings

At the beginning of the project a grounded theory approach to understanding the sites was used, though as the project evolved the analysis was increasingly influenced by a social practice theory perspective[10]. By making practices the focus of analysis, rather than the individual or the social system, practice theory provides a lens which avoids the traditional dichotomy of agency vs structure, and at the same time allows a role for materials and technology alongside more traditional sociological focuses such as meanings. It is an approach well suited to understanding the mundane activities of everyday life and how they evolve.

A number of aspects make energy a difficult resource to manage effectively within organisations. This is despite the fact that current technology, particularly BEMS and smart meters allowing automatic meter reading (AMR), seemingly provides the tools necessary for highly optimised energy management, even within highly complex, distributed organisations such as councils and large enterprises with multiple distinct sites. The ethnographic work established a number of findings around the day-to-day management of energy in the workplace, the key ones being included here.

FM and EM roles have become increasingly important

Socio-technical and organisational changes have, in recent decades, centralised energy management in the hands of FM and EM. At the level of individual sites, the contemporary office environment is one in which energy consumption is increasingly rationalised, using systems that operate automatically based on formalised rules about working hours, standards of comfort, and so on. As part of this process, individual building users' agency is curtailed, as room thermostats, radiator valves, light switches and window latches are stripped out, superseded by BEMS remotely adjusting vents, heat sources, lighting and air conditioning. This process centralises energy management in the hands of FM.

At the organisation level, a similar process of centralisation has occurred. The increasing complexity of BEMS, combined with the growing size and complexity of organisations distributed across multiple sites (in the case of councils many of these sites are no longer actually within the organisation but the energy management infrastructure remains), has seen local oversight at many sites disappear, in favour of remote monitoring by EM.

This attempt to rationalise energy management has struggled, as FM face a number of competing, at times contradictory, rationales guiding energy management[11]. One manifestation of these tensions is the resistance of office occupants to attempts to strip them of agency over the conditions they work in. Communications between FM and staff consisted almost exclusively of complaints from the latter to the former. All FM teams studied had experience of managing 'in spite' of this feedback, even in many cases *pretending* to make changes in an effort to placate staff. Despite this, at all the sites studied, cases were found where staff reasserted control in various ways – commonly recruiting senior managers to back up their demands upon FM. It was also observed that staff strategies for wrestling back control are evolving, with the increasingly data-based approach of FM and EM being matched by staff making use of their own sources of data, such as thermometers to evidence claims of unsuitable temperatures in the office.

[10] Shove, E. and Pantzar, M. (2007) 'Recruitment and reproduction: the careers and carriers of digital photography and floorball' Journal of Human Affairs, 17: 154-167.
[11] Goulden, M. Spence, A. (2015). Caught in the middle: the role of the facilities manager in organisational energy use, Energy Policy 85. 280–287

Energy is (normally) not a priority

Perhaps above all else, whilst workplace energy consumption is substantial when aggregated at a national level, within any white-collar organisation it is rarely more than a small element of expenditure, dwarfed by the cost of staff wages. The exception to this is where energy maintains additional services besides basic office functions, for example, at one of our partner sites studied there was a large number of computer servers. Even here though, the energy management of the servers was entirely separate from the management of the rest of the organisation's use. The upshot of this situation is that energy management is rarely, if ever, given priority by senior managers. As a result, energy management was commonly found to be under-resourced, with FMs 'running to stand still', so having little opportunity to optimise. Where energy savings came into conflict with other concerns, most notable staff comfort demands, senior management tend to prioritise other concerns.

Energy cuts across organisational divisions

The management of energy is also difficult due to the role energy plays within the working of the organisation. The *organisation of work* with an organisation relies on the compartmentalising of tasks. Energy, however, is everywhere, with the potential to impact on any role. As a result, in regards to energy, FM's commonly were more of a 'service provider' than 'manager', their efforts subject to the demands of others in the organisation with different, at times contradictory, energy rationales[10]. Additionally, where energy functions were considered particularly critical, most notably around IT systems such as servers, all oversight and control was removed from EM and FM. Attempts to reduce energy use were observed to often flounder in the face of these challenges.

Effective communication strategies between disparate parts of the organisation is a key element to improving energy management. Given the fact that FM have almost total control, at least in principle, over the environmental conditions of the office, it is remarkable how poor communications currently are between them and staff. This consists almost entirely of staff complaints. The FM role tends to be highly reactive, responding to complaints but rarely communicating information proactively. At one site where the FM did send out updates, it was only in the form of overly technical information on maintenance, which most staff dismissed as irrelevant to their concerns. This reactive stance is partly an unavoidable response to the 'firefighting' aspects of the role - responding to equipment breakdowns for example is a major part of the job. It arguably is self-perpetuating however – by not leading communications with building users, FMs risk ending up following them.

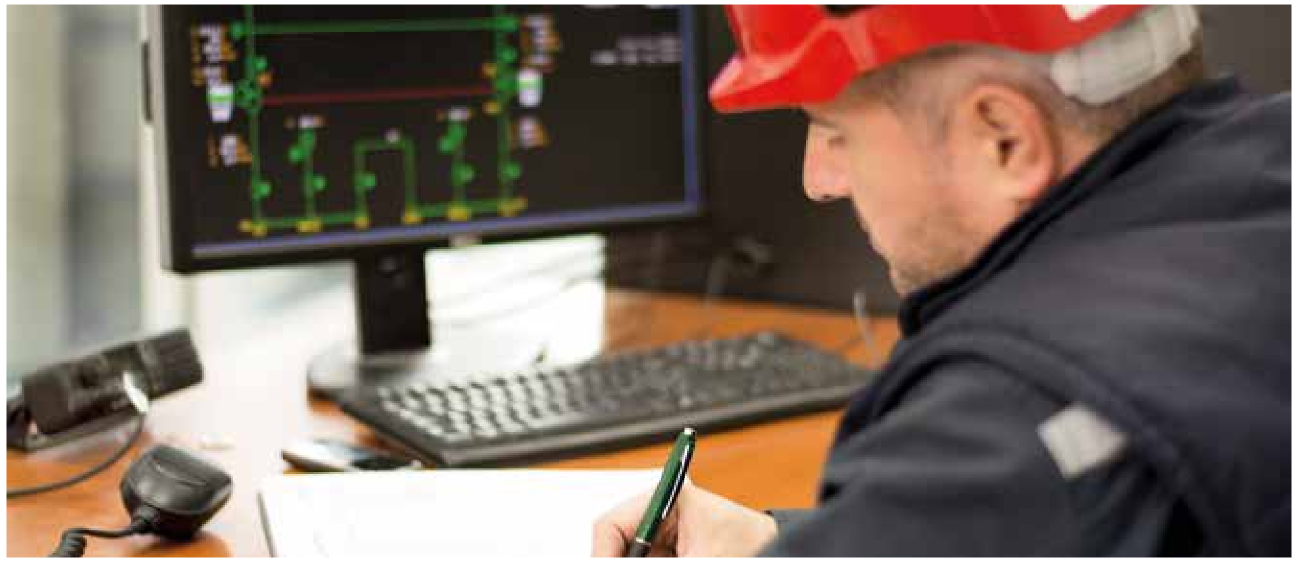
Managing energy within organisations presents a highly dynamic challenge

Due to the manner in which energy threads through all aspects of the organisation's functioning, energy management is subject to constant revision, both in terms of demand for it, and demands placed upon its management. At the level of policy, there are evolving demands for reporting and benchmarking, both from instruments such as the carbon reduction commitment (CRC) and display energy certificates (DECs), and efficiency schemes such as the public sectors' Salix, which fund improvements on the basis of benchmarked evaluations. There are also the emerging pressures to time-shift demand, through TUOS and DUOS charges[12]. There are also changing expectations of staff within the workplace of what levels of thermal comfort are acceptable. Energy demands are also continually changing within different parts of the organisation as staffing numbers and technologies change. Whilst funding was seen to be available for capital expenditure on energy management where payback within required time frames could be shown, ongoing operating expenditure to manage the evolving demands around energy were often seen to be lacking. The 'lock in' effects of existing infrastructure and practices further complicated the ability to respond to changes.

Too much data and not enough knowledge

Contemporary BEMS and AMR systems generate vast quantities of data showing near real-time and historic consumption, as well as environmental and equipment conditions in the building. Harnessing this data – for example to identify potentially wasteful heating patterns – is resource intensive, to the degree that both FM and EM teams observed were rarely able to make full use of the opportunities created. Part of the challenge stems from the fact that – for all the data captured – key information was still missing. For EM teams trying to reduce wasteful energy use, consumption data is only part of the puzzle. Key information on the practices using that energy were largely absent from current reporting systems. The assessment of wastefulness is impossible without this information. By way of example, an EM team member at a council can identify heating use on Saturdays at a distant school site, but without information on whether the school runs events that day is unable to act. There are also possible benefits from having greater granularity of data and control, to better identify where energy is being used, or better target its use. There is an obvious tension here with the problem of data overload already alluded to. This could be resolved to some degree by partial automation of the data processing, and indeed reporting software is beginning to incorporate algorithms which can, for example, flag potentially out-of-hours heating. Such approaches still rely on human resources to check and act upon the information however.

[12] TUOS (Transmission Use of System) and DUOS (Distributed Use of System) are charges for using transmission networks to gain your electricity supply. By shifting use to off peak hours, these charges can be reduced.



Conclusions

There is a strong case to be made that **the current centralised energy management paradigm is ineffective**. The model of centralised control assumes a technology-enabled expert can run the building environment to the satisfaction of a majority of users, whilst minimising energy costs. However, at the sites studied during CTECH there was only very rarely the belief that energy use was being optimised, and studies repeatedly find low levels of occupant satisfaction within office buildings with centralised control. The centralisation of energy has created a set of problems of coordination and there is **clear value in FM energy management being more proactive and less reactive** (though we recognise problems in training needs and underresourcing). We propose that the agency of building users be better recognised by workplace energy management, but that simultaneously they should have their comfort expectations placed in the context of the cost of meeting those expectations. In other words building occupants should have more power and more responsibility.

Digital technologies hold out promise for addressing some of the shortcomings identified here. Recent developments in 'smart infrastructure' seek to enable self-monitoring and reporting to identify problems ahead of time. This holds out the potential for reducing the fire-fighting aspect of FM, giving them more scope to switch from responsive to proactive. For EM, algorithms and the capture of vital contextual information raises the possibility of automating some of the optimising work done (or aspired to be done) currently. **However, technology interventions need to be more attuned to the contexts in which they are used** – there was a consistent pattern in the sites studied of overly complex, insufficiently user-friendly BEMS being under-used by FM too busy 'keeping the lights on' to delve into these systems. Technology is only part of the solution however – FM practices need to adjust, and future developments should recognise that building energy systems are social as well as technical.

Relevant Outputs

Goulden, M. and Spence, A. (2015). Caught in the Middle: The Role of the Facilities Manager in Organisational Energy Use. Energy Policy. 85, 280-287.

The paper by Goulden and Spence also won a prize from the British Sociological Association Climate Change section (2016).

People's use of, and interactions around, energy at work

2

People's Use of, and Interactions around, Energy at Work

Getting communications around energy saving initiatives to building users right is important in order to gain acceptance and engagement. We developed a series of surveys and quasi-experimental studies in order to examine how people currently consider energy saving in the workplace and how they may respond to new digital energy technologies within their workplaces. We find that motivations to save energy are generally very high and that people are highly motivated by helping their organisation or supporting their colleagues as well as by environmental issues. People are often angry when others overuse energy and prefer institutional sanctions to meet this problem. Energy feedback can be useful in prompting behaviour change and we observe that absolute numbers provided to people are important, and the small numbers involved with the feedback of costs can be demotivating.

Current advances on reducing energy use in workplaces has mostly focused on improving appliances, system efficiency, or appointing key personnel with energy responsibilities (e.g., facilities managers, eco-champions)[13]. There has been little investigation of how normal, individual workers (with no energy responsibilities) may change their own energy use behaviour to reduce emissions. Since energy use is not an element of most employees' job assignments, and is usually not taken into account in performance evaluations, it might be argued that people simply will not care about, or act to save energy.

Our research focused on examining the motivations employees have to reduce their energy use at work, and how people engage and interact around energy and digital energy tools. Interestingly, to date, the *purpose* of energy saving in the workplace, that is for what or for whom employees would save energy, has not been studied as a precursor of energy saving intentions. We focused on establishing potential motivations that employees can have to reduce their energy use.

We also examined the way in which building users interact with energy data and visualisations. Energy usage displays are now being utilised in workplaces in various forms, primarily using energy usage graphs, but also sometimes with simplified representations intended to be more engaging, e.g. happy or sad faces[14] however their impact in a shared context where people do not pay for their energy use is under explored. We were particularly interested in how energy information is presented to building users in relation to motivations to save energy. Research here focused on the effectiveness of financial information and environmental information in prompting energy saving intentions.

Notably research in energy saving at work has been scarce until now, and the little research that does exist has primarily focused on individual behaviour[15]. However as already noted, in the workplace, energy use is a communal situation where employees share the energy of their company, and thus any efforts to reduce the consumption will have to be shared as well. Interactions between employees around energy use, and how people react to visualisations of their own and others energy use, has not previously been investigated in this context.

[13] Aragón-Correa, J. A., Matías-Reche, F., & Senise-Barrio, M. E. (2004). Managerial discretion and corporate commitment to the natural environment. Journal of Business Research, 57, 964-975.
Cordano, M., & Frieze, I. H. (2000). Pollution reduction preferences of US environmental managers: Applying Ajzen's theory of planned behavior. Academy of Management Journal, 43, 627-641.
[14] http://smartspaces.dmu.ac.uk
[15] Staddon, S. C., Cycil, C., Goulden, M., Leygue, C., & Spence, A. (2016). Intervening to change behaviour and save energy in the workplace: A systematic review of available evidence. Energy Research & Social Science, 17, 30-51.

Findings

Motivations to save energy at work

The extent to which employees will try to reduce their energy use might depend on a number of motivations including if they see it as a key aim of their job[16] or if they are motivated by more proactive prosocial behaviour among employees. We aimed to investigate what motivates employees to reduce their energy use at work when their job specifications do not include it. Indeed, energy saving can be considered an "extra-role" and altruistic behaviour, as for the individual it is not normally directly or explicitly rewarded, but collectively is positive for the organisation[17]. However, previous research on prosocial behaviour has shown that altruistic acts could also be motivated by self-oriented drives (e.g., warm-glow: positive feelings about oneself for doing the right thing), and in the workplace, people might also be motivated by being approved by their management or peers for saving energy.

We hence developed a scale of Motivations to save Energy at Work (MEW) that contained both altruistic and self-oriented items. We tested this scale and how well it predicted energy saving behaviour and sustainable choices in three studies. In study 1 (N = 293), we factor analysed the 28 items of the scale and they grouped into 6 factors (see appendix table 1). Behaving altruistically towards your organisation (in terms of saving your organisation money or helping your organisations image) and environmental concern were rated as the most important motivations to save energy at work. Self-oriented motivations, such as feeling good as a result of your actions (warm glow), and reluctant altruism (a feeling of duty to act as others will not) were also rated as an important motivation to save energy. Reputation building was not rated as an important motivation to save energy. People rated the different motivations to save energy at work similarly in terms of importance in two further studies indicating that this pattern of results may be comparable across organisations in the UK. Our studies used a range of samples: study 1 was conducted in two large organisations, one private and one public; study 2 (N = 94) used an opportunity sample drawn from three small to medium sized companies; and study 3 (N = 1552) consisted of a broadly representative sample of the UK in terms of age, gender, social grade, and location.

We also examined how well intentions to save energy were predicted by the different reported motivations. In study 1, intentions were predicted primarily by motivations to save energy due to environmental concern and the desire to help your organisation's image. In study 2, again energy saving intentions were predicted by motivations to save energy due to environmental concern but here motivations to help their organisations finances and to feel good about their energy saving behaviour (warm glow) were also significant predictors of energy saving behavioural intentions. The differences in the extent to which various motivations predicted energy saving behaviour across organisations indicate that these may be context dependent, notably dependent on the size and the culture of the organisation. Indeed, the organisations in study 2 were smaller than in study 1, and smaller organisations may profit more from saving on energy costs.

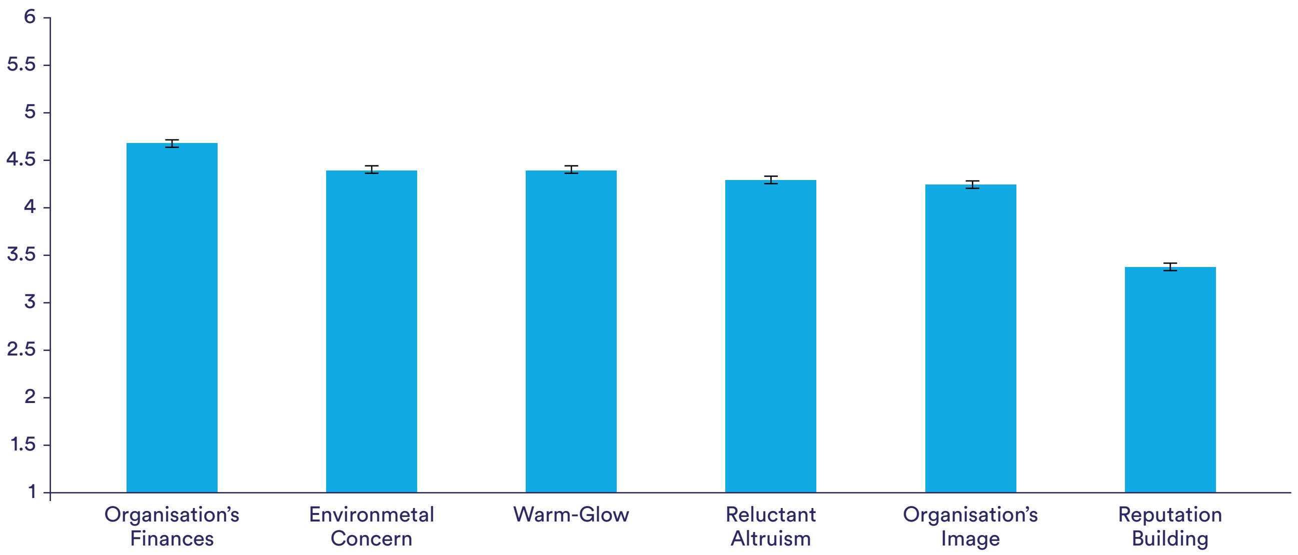


Figure 2. Mean scores for motivations to save energy at work for study 3. The error bars represent standard errors. Note that 3.5 represents the midpoint of the scale and mean values below this indicate that participants rate the motivation as not very important.

[16] Rioux, S. M., & Penner, L. A. (2001). The causes of organizational citizenship behavior: a motivational analysis. Journal of applied Psychology, 86, 1306.
[17] LePine, J. A., Erez, A., & Johnson, D. E. (2002). The nature and dimensionality of organizational citizenship behavior: a critical review and meta-analysis. Journal of Applied Psychology, 87, 52-65.

We examined these further in study 3, using a nationally representative sample. Here energy saving behaviour intentions were predicted by environmental concern motivations, motivations to feel good about their behaviour (warm glow), motivations to help their organisations image and motivations to help because it was unlikely that anyone else would, see Figure 2.

Interestingly, the higher that people rated their motivations to promote their reputation at work, the lower their intentions were to save energy across all three studies. It may be that people would prefer to be seen as focusing on core work duties rather than energy saving at work, or that they would be interested in energy saving whether these actions affect their reputation or not, or simply that they are not very concerned with their reputation. Further analyses within study 3 revealed that reputation building was related to higher energy saving intentions when people perceived that the company valued energy saving.

Effects of energy displays

The British government, through energy companies, proposes to rollout smart meters across homes and small businesses by 2020. Research has shown that associated energy displays that will be provided alongside smart meters can help consumers understand energy use and to reduce their energy usage[18]. However, we note efficacy of energy displays is still highly variable between contexts, and the necessity of people's engagement is frequently discussed. We were interested in particular in comparing costs (feedback in sterling pounds) with environmental information (feedback in CO2) as they target different motivations, and possibly opposing values[19] and can affect environmental behaviour in different ways[20].

We conducted two online studies where participants read scenarios about an energy saving campaign associated with energy use displays showing usage in terms of environmental consequences (Kg of CO_2 emissions), or financial consequences (amount of sterling pounds), or both. In study 1 (N = 93), the use of CO_2 units for feedback (compared with cost) significantly increase participants' feelings that their savings can make a difference (known as instrumentality). This, in turn, increased energy saving intentions. So presenting environmental consequences seemed to be better at encouraging energy use. We considered that this could be due to the fact that cost feedback typically shows numbers that in absolute terms are low, compared to environmental feedback (e.g., £2 of saving compared to 8 Kg of CO2), and this might discourage people to make efforts.

Indeed, these effects disappeared in study 2 (N = 142), in which we controlled for absolute differences in numbers presented (which are naturally higher in CO2 compared to £) to examine differences in units only. Results reveal that units alone do not affect participants' feelings that they can make a difference. Furthermore, the cost display was similarly impactful to CO2 displays, and more impactful than displays combining cost and C02 information, in increasing energy saving intentions and further sustainable choices. To conclude, cost displays seem to discourage energy saving only when it shows numbers that are lower than the other displays; if the numbers are equalised, showing cost is just as impactful.

Social interactions around energy use at work

In the workplace energy is shared by employees, making it a public good that employees cooperate in using. Energy saving efforts must similarly be collective. As a consequence, putting in place energy saving campaigns or interventions in the workplace can be conceptualised as a social dilemma for employees. Indeed, it could be considered that the benefits to the group/the organisation (saving a lot of electricity to save costs) oppose the benefits to the individual (using electricity to work comfortably and not waste time).

We know from previous research that in a social dilemma context, people can cooperate and reduce their energy use, or decide to act selfishly and use more than their fair share (free-ride). Previous research has shown that when a group is sharing their energy and energy bill, if people are not able to reprimand people who use too much, we observe an escalation of energy use[21] because people feel angry towards free riders and start using more energy themselves. In addition, our previous research has also shown that these reactions around energy use are affected by energy displays. When people are given detailed information on displays about who is using what (e.g., through feedback on individual energy use), they feel more angry towards people who use too much than if total energy use information is provided; they are also more likely to want them to receive some form of sanction (e.g., pay a fine)[22], and are less likely to want to reduce their energy use themselves.

[18] Darby, S. (2006). The effectiveness of feedback on energy consumption: A review for DEFRA of the literature on metering, billing and direct displays. Oxford, UK: Environmental Change Institute.
Buchanan, K., Russo, R., & Anderson, B. (2014). Feeding back about eco-feedback: How do consumers use and respond to energy monitors? Energy Policy, 73, 138-146.
[19] Evans, L., Maio, G. R., Corner, A., Hodgetts, C. J., Ahmed, S., & Hahn, U. (2013). Self-interest and pro-environmental behaviour. Nature Climate Change, 3(2), 122- 5.
[20] Spence, A., Leygue, C., Bedwell, B. and O'Malley, C., (2014). Engaging with energy reduction: Does a climate change frame have the potential for achieving broader sustainable behaviour? Journal of Environmental Psychology, 38, 17-28.
[21] Skatova, A., Spence, A., Leygue, C., & Ferguson, E. (2017). Guilty repair sustains cooperation, angry retaliation destroys it. Scientific Reports, 7.
[22] Leygue, C., Ferguson, E., Skatova, A., and Spence, A. (2014). Energy sharing and energy feedback: Affective and behavioral reactions to communal energy displays. Frontiers in Energy Research, 2, 29.

Notably, in the workplace, employees may prefer institutional answers to people who use too much energy, as opposed to acting themselves. Furthermore, there is a gap in the literature concerning cases when people are legitimately unable to make any effort to contribute to energy saving initiatives by reducing their energy use. The literature has focused on situations where people use too much because they do not make any effort, however, there are cases where people use more energy than others because they need to, and cannot reduce their use, for example, an individual might have a medical condition that would benefit from the use of a dehumidifier, or require use of lifts rather than stairs. In these cases, these could be considered as legitimate free riders.

In a further large national survey (N = 1552), we asked participants to read scenarios about an energy saving campaign in the workplace. In this scenario, they had to imagine that a colleague was using too much energy. In the legitimate free riding condition, it was specified that this colleague needed to use a humidifier for health reasons. In the classic free riding condition, it was not specified why they were using it (in the control condition, there was no overuse). Results showed that participants feel more anger and fear when energy use increases above normal standards. However, when asked about how to react towards people who use too much, participants preferred their manager or environmental champion to do something about the overuse, rather than wanting to confront people themselves. Also, we observed that people are less angry and react less negatively when people have a legitimate reason to use more. They are even ready to reduce their own usage of electricity to compensate for this “fair overuse”.

So, we find that even if electricity use is of no financial costs to them, employees can react negatively when a colleague is using too much energy. However, specifying why people use more than others can reduce negative reactions, and implementing institutional consequences can help in avoiding potential conflict between employees.

Conclusions

We found that employees could be motivated to save energy with the aim of **helping their organisation or supporting their colleagues**, so energy saving campaigns would benefit by focusing on these benefits as well as on environmental benefits as is common. We also found that encouraging energy saving as a means to aid your reputation at work (e.g., evaluation from management) is unlikely to be effective, and actually could be counterproductive and discourage people to reduce their use, unless the organisation clearly values energy saving.

If a an energy saving intervention includes the use of energy feedback, the **choice of units for the feedback is important**. If the display includes numerical feedback, the small numbers in a cost display (with some currencies at least, such as pounds or euros) is likely to reduce energy saving intentions. However, the superiority of carbon units disappears when actual numbers are kept constant: then we see that a cost feedback might be more impactful on energy savings.

Finally, campaigns around energy saving in the workplace should take into account **social interactions**. Indeed we found that employees can be angry when others use too much but also accepting that some people may need to use more energy than others. There is a sense of fairness in allocating share of energy consumption. Specific institutional sanctions to overuse can be put in place to avoid discord, and legitimacy of energy use can be clearly defined to encourage cooperation between colleagues.

Relevant Outputs

Leygue, C., Ferguson, E., Skatova, A., and Spence, A. (2014). Energy sharing and energy feedback: Affective and behavioral reactions to communal energy displays. Frontiers in Energy Research, 2, 29.

Spence, A., Leygue, C., Bedwell, B. and O’Malley, C., (2014). Engaging with energy reduction: Does a climate change frame have the potential for achieving broader sustainable behaviour? Journal of Environmental Psychology, 38, 17-28.

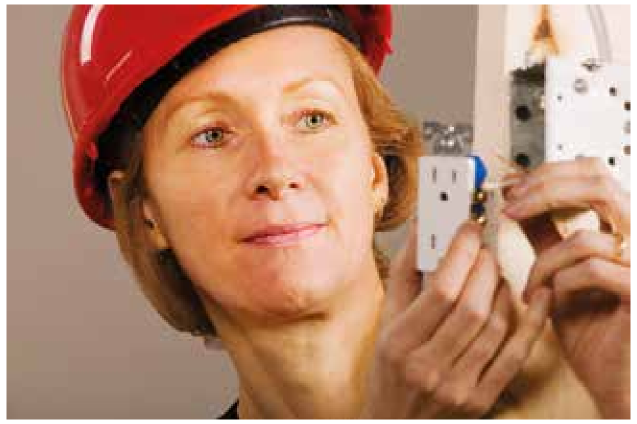
Skatova, A., Spence, A., Leygue, C., and Ferguson, E. (2017). Guilty repair sustains cooperation, angry retaliation destroys it. Nature Scientific Reports.

The Technicalities of Energy Monitoring

3

The Technicalities of Energy Monitoring

Joining energy monitoring devices to a network can be the most difficult part of using these devices. Configuration approaches need to be intuitive and perform well if end users are to be able to incorporate, and rely on, these devices in their daily lives. We conducted two usability studies to identify the best interaction technique to support users in connecting low-power, low-cost Wi-Fi devices with very minimal user interfaces to an existing, secure Wi-Fi infrastructure. Studies indicated that web configuration, where a user connects to an access point on the device, and audio configuration, where the network details are sent over an audio cable that connects the smartphone to the device are most easily used.



While most workplace energy-monitoring systems are complex and installed by specialist service providers, there is an ever-expanding choice of cheaper, simpler off-the-shelf “Internet-of-things” (IoT) devices that can be installed by FMs, EMs and staff to collect data on workplace energy use and environmental conditions. These devices are designed to be bought, unboxed and connected to an existing local network, often wifi, which is then used to send data back to a central service that visualises the data for the building occupants.

We are specifically interested in small devices, such as battery-powered wireless sensors, displays or actuators. These devices, hereafter referred to as ‘Wi-Fi devices’ include very minimal user inferfaces (UIs: Simple lights rather than graphic displays, single buttons rather than keyboards) making it difficult for a person to input information directly into them. Instead the task can be supported by an external device with a more complete UI such as a smartphone, an ubiquitous, always at-hand object. In practical terms, for a new Wi-Fi device to join an existing (secured) Wi-Fi network, the network name (“SSID”) and password must be somehow entered. Our focus was to discover the best method to allow users to transfer Wi-Fi network names and passwords from a smartphone to a Wi-Fi device with little or no UI. We restricted the design to only use low cost hardware, recognising practical cost constraints of potential users.

Wireless Node Configuration Study.

We prototyped four different interaction techniques for the configuration of low-cost off-the-shelf wireless sensor nodes that can be deployed for feedback interventions in workplaces (e.g. partner sites). The choice of techniques was informed by technical constraints that would allow them to be realistically adopted on a Wi-Fi device, as well as by the techniques already integrated in off-the-shelf products.

Two lab studies (both N = 30) compared these techniques. In each study, the participants configured WI-Fi devices with very basic user interfaces using a variety of techniques (different groups of techniques were compared in each of the two studies), inspired by methods already adopted by products on the market. To understand the issues encountered by our participants during the study, we performed a video analysis of how participants performed in the study.

Two researchers individually coded the footage for errors that occurred during the configuration process. Figures 3 and 4 show the success rate of the two studies, i.e. how many times participants successfully completed the task with each of the interfaces. This analysis, together with questionnaires that examined participants subjective preferences about the different techniques indicate that two configuration approaches are more usable and would be best suited to set up Wi-Fi devices. These are web configuration, where a user connects to an access point on the Wi-Fi device, and audio configuration, where the network details are sent over an audio cable that connects the smartphone to the device.

Conclusions

Configuration approaches **need to be intuitive and perform well** if end users are to be able to incorporate, and rely on, these devices in their daily lives. Therefore, we hope that our results will stimulate discussion and further work related to actual deployments of sensor systems that take advantage of the prevalent Wi-Fi infrastructure.

Web configuration and audio configuration are most suitable for setting up Wi-Fi devices with basic user interfaces. Both present inherent benefits and limitations in terms of technical requirements. Web configuration requires little by way of extra hardware, but needs more platform specific instructions and software integration. Conversely, audio configuration is more platform-agnostic, but requires a cable and a few extra electronic components.

Relevant Outputs

Jewell, M. O., Costanza, E., Kittley-Davies J. (2015). Connecting the Things to the Internet: An Evaluation of Four Configuration Strategies for Wi-Fi Devices with Minimal User Interfaces. In Proc. UbiComp ’15.

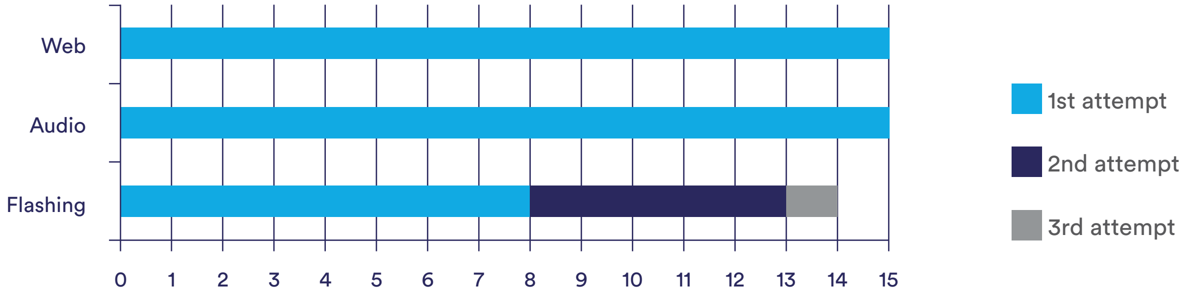


Figure 3. Overview of participants’ performance in Study 1, showing the number of participants who successfully completed the task within 3 attempts, using different interaction strategies.

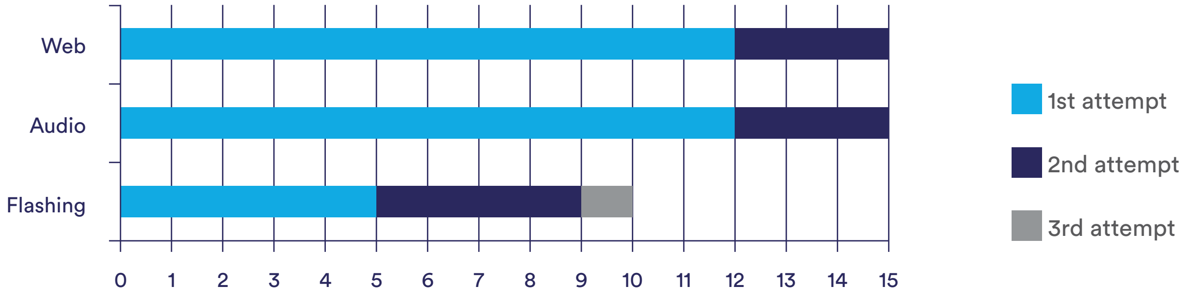


Figure 4. Overview of participants’ performance in Study 2, showing the number of participants who successfully completed the task within 3 attempts, using different interaction strategies.

Digital Interventions for Energy Visualisation and Engagement in the Workplace

4

Digital Interventions for Energy Visualisation and Engagement in the Workplace

Currently there is lots of energy data available in workplaces but often little understanding of that data. We have particularly focused on the potential of visualising energy use in order to engage building users with energy efficiencies and savings. IdleWars is a pervasive game designed to raise awareness and promote behaviour change in relation to energy waste in the workplace. The Temperature Calendar is a visualization of temperature variation within a workplace over the course of the past week. The Always-on Calendar is a visualization of the baseline electricity consumption (i.e. the minimum consumption level, which is normally overnight) over the course of the past week, comparing each day with the previous one. We found that that pervasive games such as IdleWars can turn a conversation about energy management into a fun, active and engaging process. Visualisations of current building operations (e.g. the Temperature calendar) can raise understanding of energy consumption and encourage action. In particular studies helped us to reflect on the potential for energy feedback tools to engage with the application of new organisational policies, as well as supporting policy development.

Considerable attention has been given within academic literature to "Ambient Displays" – defined as displays "designed to be minimally attended and perceivable from outside of a person's direct focus of attention, providing a level of pre-attentive processing without being unnecessarily distracting"[23]. Our work differs from ambient displays in that it is directed at users explicit attention. Closer to our work, Valkanova et al. report the design and evaluation of Reveal-it!, a public display that shows a comparison of self-reported energy consumption[24]. Results from 3 deployments in public locations for a total of 20 days suggest that the Reveal-it! display was largely successful in engaging the audience in reflecting about their own energy consumption, comparing it to the consumption of others. Our work is similar to Reveal-it!, in that it also involves public displays related to energy, and they require users' explicit attention. However, our approach is different in several ways: first our emphasis is on sensor data, rather than self-reported; moreover, while our display is also public, it refers to one specific workplace building and its users, rather than individuals and communities from the local area.

Public or communal displays have been used to engage building users within both domestic and work environments. There is now a significant body of work that describes interventions that seek to reduce domestic energy consumption, however the work environment is an under-researched setting[25]. Some off-the-shelf displays exist for workplaces, e.g. the LEED Dynamic Plaque, revealing the performance of buildings against benchmarks. Researchers have also explored displays that incorporate a range of feedback strategies, including comparing the energy efficiency of teams in a production setting[26], and tracking and visualising individuals' resource use in offices[27]. The academic community in this area has been criticised for a focus on the individual, limiting the potential to address broader energy savings[28]. In line with this, our displays aim to reveal patterns in communally-used energy.

[23] Hazlewood W., Stolterman E. and Connelly K. 2011. Issues in Evaluating Ambient Displays in the Wild: Two Case Studies. In Proceedings of ACM CHI '11, p. 877–886.
[24] Valkanova N., Jorda S., Tomitsch M. and Vande Moere A. 2013. Reveal-it!: The Impact of a Social Visualization Projection on Public Awareness and Discourse. In Proceedings of ACM CHI '13, p. 3461–3470.
[25] Pierce J. and Paulos E. 2012. Beyond Energy Monitors: Interaction, Energy, and Emerging Energy Systems. In Proceedings of ACM CHI '12, p. 665–674.
[26] Siero F., Bakker A., Dekker G. and Van Den Burg M. 1996. Changing organizational energy consumption behaviour through comparative feedback. Journal of Env. Psych. 16:3, p. 235–246.
[27] Pousman Z., Rouzati H. and Stasko J. 2008. Imprint, a Community Visualization of Printer Data: Designing for Open-ended Engagement on Sustainability. In Proceedings of ACM CSCW '08, p. 13–16.
[28] Knowles B., Blair L., Coulton P. and Lochrie M. 2014. Rethinking plan A for sustainable HCI. In Proceedings of ACM CHI '14, p. 3593-3596.

IdleWars

"Ambient displays" are typically placed into an environment to be discovered, stumbled across or otherwise encountered as part of typical daily routines. The majority of our work focused on how informative visualisations might be placed into strategic locations around the workplace (e.g. Temperature Calendar, Always-on, and ultimately e-Genie), but we also studied whether visualisations on public displays might be used as part of a more active workplace game.

Figure 5. An idle computer displaying a QR code, about to be 'busted'.

Our results suggest that such games might be a good starting point for adjusting and launching workplace policies around energy management, and particularly for bringing staff into this process. Our results also demonstrate the dangers of using games as an engagement tool: with our initial IdleWars design it was possible to develop playing tactics that were less sustainable but still "won" the game. Designers of pervasive games to encourage sustainability will need to evaluate their games in-the-wild to sensitise themselves to opportunities for players to "game" the system in unsustainable ways.

Visualising building operation: design motivations

For the Temperature Calendar and the Always-on Calendar, our design was motivated by seminal work in the fields of design and human-computer interaction (HCI) that highlighted the likelihood of user *errors* in the configuration and use of complex and "intelligent" systems[29]. Importantly - as more intelligent or complex energy management systems distance the building occupant from the working of the building – errors can go unnoticed by users, but still waste energy. Researchers have demonstrated that domestic users make errors with automated systems, e.g. participants from a domestic smart study only realised that their air conditioning was left on unnecessarily when they are away from home, thanks to interviews during a research study[30].

Ways to avoid and mitigate errors are under-investigated issues in sustainable HCI, particularly in the workplace context. As highlighted in previous sections of this report, staff – even FMs and EMs – can be remote from the management of heating, lighting, cooling and other complex workplace systems, in terms of understanding, control and responsibility[31]. We conducted two workshops in a county Council, one to discuss energy consumption data with managers and one with office staff, to reveal how the different stakeholders understood energy consumption in their building. Qualitative data from these workshops highlight the challenges for any members of staff to understand how energy is used in the workplace, because of the complexity of the building infrastructure. The act of bringing together these stakeholders to discuss consumption data forced the staff to begin questioning the ways that the buildings were set up to operate. In parallel, our independent analysis of the Council's energy consumption data revealed specific instances where energy was wasted because of errors in the way the heating and domestic water infrastructure had been configured. It is worth underlining how such wastage was not related to anyone's comfort or convenience, factors often understood as drivers of consumption[32].

We saw potential for interactive technology to help identify and rectify such errors in energy usage. Our hope is that by visualizing (some of) the building operation, occupants would gain a better understanding of energy processes in their local building environment, enabling them to detect errors or problems, and possibly act upon them. In some cases such action may not be in direct terms, as often building inhabitants (e.g. employees) may have limited or no control over the infrastructure settings, which may be instead operated by facility management and engineering services internal or external to the organization. Still, increased understanding, or even data to substantiate requests for changes, should be beneficial in supporting the dialogue or negotiations between the inhabitants and facility managers.

Temperature Calendar

The Temperature Calendar displays the temperature for the past seven days, hour by hour, with a format similar to a week diary planner, as illustrated in Figure 6. Each column corresponds to a calendar day, labelled on the top, with the rightmost column corresponding to today. Each column is divided into 24 cells, corresponding to the hours of the day, these are labelled on the left at four hour intervals. Cells are coloured according to the average temperature recorded for that hour, on a colour scale that goes from white to orange, corresponding to the minimum to maximum temperatures for the seven days displayed. The minimum and maximum daily temperatures are indicated on each column with numerical labels in grey or red, respectively. These labels also aim to provide a reference to more easily interpret the colour gradient on the display. Cells can be highlighted with a blue or red coloured vertical bar on the right, to indicate that the temperature is respectively below or above the range prescribed in the organisational temperature policy, where such policy is available.

[29] Norman D. 2013. The design of everyday things. Basic books, New York, USA. and Reason R. 1990. Human error. Cambridge university press, Cambridge, UK.
[30] Yang R., Newman M. and Forlizzi J. 2014. Making sustainability sustainable: challenges in the design of eco-interaction technologies. In Proceedings of ACM CHI '14, p. 823-832.
[31] Goulden M. and Spence A. 2015. Caught in the middle: The role of the Facilities Manager in organisational energy use. Energy Policy 85, p. 280-287.
[32] Shove E., Walker G. and Brown S. 2014. Material culture, room temperature and the social organisation of thermal energy. Journal of Mat. Cult. 19:2, p. 113–124.

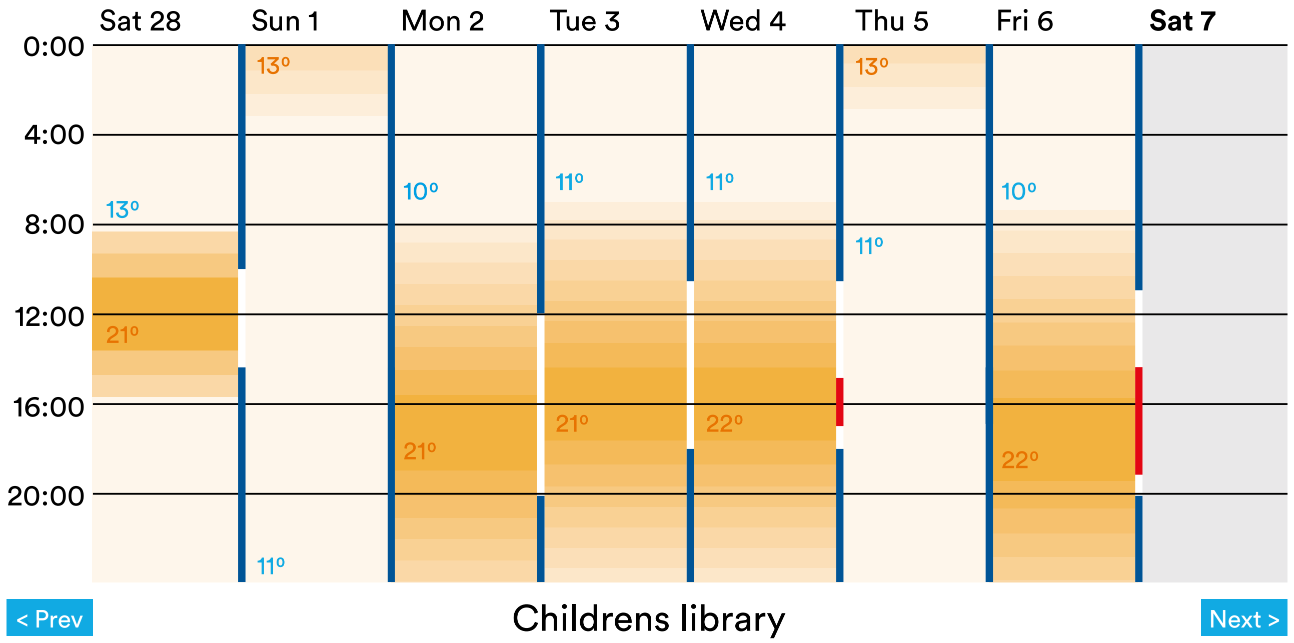


Figure 6. The Temperature Calendar.

The Temperature Calendar visualization was deployed in the wild in 8 workplaces, including public libraries, a hospital, and two office buildings. A combination of quantitative and qualitative data revealed that calendar visualisations can sensitise building inhabitants to heating patterns and how the building responds to external weather conditions and the daily movement of the sun and encourage action to mitigate issues and "errors". Our interviews with staff who used the display – confirmed with energy consumption data from the workplaces – revealed that staff in four workplaces had gone on to take practical action and experiment with their heating systems to solve heating issues. In some cases the actions were extreme - turning entire heating systems off to see whether the impact would be bearable - while in other cases staff experimented by being more strict about turning off individual heaters, particularly when there was a suspicion that these heaters were operating out-of-hours or when staff were not around (i.e. "errors" in their initial configuration). Staff used the calendar to construct narratives that explained internal temperatures through the day and the week. These narratives were challenged and developed further in the workshops conducted at two of the sites and thus demonstrated the need for an opportunity for staff to work through the rich calender data with others in coming to further insights about thermal management of the space.

The Temperature Calendar also visualised how the temperature deviated from the workplace temperature policy. Our interview results show that some staff felt that the temperatures dictated by the policy were simply inappropriate to their particular context; others saw the Temperature Calendar as a legitimate way to prove that their buildings were failing to meet the policy, and therefore deserved attention from the organisation.

Always-on Calendar

The design rationale behind Always-on Calendar is the same as the Temperature Calendar: making the operation of the building and its infrastructure visible can hopefully help building inhabitants to detect errors. The Always-on Calendar shows the baseline electricity consumption (i.e. the minimum consumption level, which is normally overnight) for the past 6 days, as illustrated in Figure 7. Each rectangle in the display corresponds to a different day, similar to the pages of a paper daily calendar. For each day, the display shows prominently whether the always-on consumption "went down", "stayed the same", or "went up" compared to the previous day – the first two options are displayed in green to highlight them as desirable, while the last one is displayed in red to highlight it as undesirable. For each day, the display also shows the actual level of always-on consumption measured in kW.

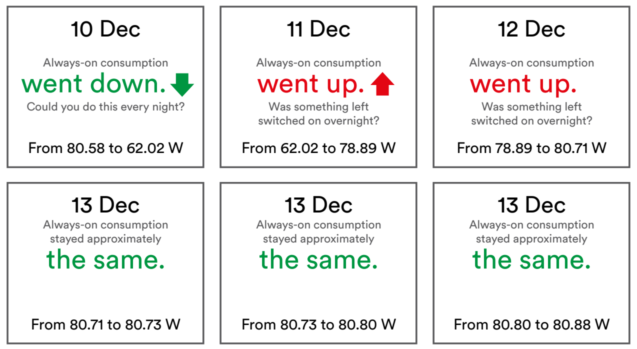


Figure 7. The Always-on calendar.

Conclusions

Our findings highlight that **interactive displays are an opportunity to bring staff into the development of organisational policy**. Even though Dourish drew attention to policy in 2010[33], relatively few projects attempted to go in such a direction – a notable exception is the “Water Wars” project[34] designed around possible water distribution policy changes in New Mexico. Jain et al mention different organization level policies related to energy consumption[35], but they fall short of suggesting how HCI can engage with them. We believe that opportunities lie not only around helping users reflect on the implementation of existing policies (as we report in this paper), but also in promoting discussion around the introduction of new policies or modification of existing ones.

Finally, we were also keen to reflect on **the hidden environmental impact of deploying new technologies to engage staff**: tablets, networking devices and sensors can have significant embedded carbon from their production, and are responsible for more emissions from the energy they use while in operation and during their disposal. A cost-benefit analysis for the Temperature Calendar – comparing the carbon emissions from the production and use of the tablet used to display the Temperature Calendar vs. the savings generated from its use – demonstrated the hidden environmental costs of using technological interventions, and provides an example for other researchers to critically appraise the impact of technological interventions.

Relevant Outputs

Bedwell, B., E. Costanza, and M. Jewell (2016). Understanding energy consumption at work: Learning from arrow hill. In Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work & Social Computing, CSCW ’16, New York, NY, USA. ACM. doi:10.1145/2818048.2819993

Colley, J. A., Bedwell, B., Crabtree, A. and Rodden, T. (2013). Exploring Reactions to Widespread Energy Monitoring. Human-Computer Interaction – INTERACT, 8120, 91-108.

Costanza, E., B. Bedwell, M. Jewell, J. Colley, and T. Rodden (2016). ‘A bit like British Weather, I Suppose’ Design and Evaluation of the Temperature Calendar. In Proceedings of the 34th Annual ACM Conference on Human Factors in Computing Systems, CHI ’16, New York, NY, USA. ACM.

Tolias, E. Costanza, E., Rogers, A., Bedwell, B., and Banks, N. (2015). Idlewars: an Evaluation of a Pervasive Game to Promote Sustainable Behaviour in the Workplace. Int Conf on Entertainment Computing.

The interactive energy game ‘Idlewars’ also won the MACE EnviroGame prize (2014)

[33] Dourish P. 2010. HCI and Environmental Sustainability: The Politics of Design and the Design of Politics. In Proceedings of ACM DIS, p. 1–10.
[34] Hirsch T. 2010. Water Wars: Designing a Civic Game About Water Scarcity. In Proceedings of ACM DIS ’10, p. 340–343.
[35] Jain M., Agrawal A., Ghai S., Truong K. and Seetharam D. 2013. ”We Are Not in the Loop”: Resource Wastage and Conservation Attitude of Employees in Indian Workplace. In Proceedings of ACM UbiComp, p. 687–696.

e-Genie (Electronic Goal-setting and ENergy Information Engagement): an interactive energy visualisation tool

5

e-Genie (Electronic Goal-setting and ENergy Information Engagement): an interactive energy visualisation tool

Beyond individual energy visualisations developed, we also developed a broader tool for engaging building users with energy and energy issues across the workplace – e-Genie. There was a clear call and need within partner sites for interventions that visualised a range of energy information and supported building users in feeding back and contributing to that energy information. e-Genie brings together findings and insights from all the different disciplines and studies conducted as part of this research project. In particular we integrate some of the previous energy visualisations discussed (the Temperature calendar and the Always on calendar) and also encourage building users to take action on this information by discussing energy issues, making individual plans for action, or contacting the facilities manager. An early version of the tool struggled to engage building users but after further development, we observed significant increases in energy saving concerns and social energy intentions after two weeks of the e-Genie installation. We propose the tool is best used in a modular way in order to fit the context and needs of the specific workplace and we plan that additional development will further increase engagement and impact.

Previous research has found mixed results with regards to the effectiveness of energy displays. We observe that it is difficult to evaluate the impact of energy displays given that these are often combined with other intervention features. However there are indications that information alone is not enough, and other features, such as additional control, automation, or interaction are likely to make this kind of intervention more successful. Many energy displays installed are simple methods of communicating energy data in a more easy to understand form however there is evidence that displays allowing user interaction may be more engaging. For example, displays in a domestic environment have demonstrated that those that allowed users to view, annotate and reflect on energy traces in the domestic environment particularly enabled users to relate energy consumption to their daily activities[36].

Our ethnographic research has highlighted the pivotal role of the Facilities Manager (FM) in the potential for achieving energy savings in a workplace[10]. Both ethnographic research and workshops conducted highlight the complexity of negotiations in energy use and management, the need to support communications between building users on this topic, and the importance of leadership from senior management in engaging with these issues[6]. From all parts of our research we repeatedly observed that the potential for individual behaviour change is often limited, and therefore we had a focus not only on individual behaviour but also beyond individual behaviour to consider collaborative *social energy behaviour* and organisational policy changes.

We found that people were particularly motivated to save energy in the workplace by helping their organisation and for environmental reasons. However, overall we particularly found that motivations to save energy in the workplace were very high. This led us to have a greater consideration of how people could be supported in transforming their motivations into behaviour. Implementation intentions[37] are a planning technique which support people in enacting behavioural intentions by creating associations between environmental cues and behaviour. For example, someone might consider that they often forget to put their computer to sleep before they leave their desk to have lunch and use the technique to create an association between the temporal cue of lunch time and the behaviour of putting the computer to sleep. Repetition of this plan is theorised to create new cues for behaviour, so subsequently when the individual encounters the cue, the behaviour spontaneously comes to mind. Implementation intentions have been one of the most successful interventions in health psychology but have only recently been applied to energy behaviour[38]. We consider that these have a great deal of potential in supporting behaviour change in this field.

As previously highlighted, we conducted a systematic review of previous interventions to save energy in the workplace. This identified enablement (providing autonomy and support to employees), modelling (various forms of social influence) and environmental restructuring (changing the physical or social context) as key features of previously successful interventions to save energy in workplace buildings[8]. Our research has considered each of these aspects and particularly focuses on how digital tools can be integrated in a way that promotes enablement and modelling.

e-Genie development

We aimed to integrate interdisciplinary insights in the development and building of a new energy engagement tool, named e-Genie (Goal-setting and ENergy Information Engagement). We integrated interactive features into this energy feedback tool in order to engage building users with their energy use rather than simply displaying energy consumption data. The e-Genie tool provides energy information feedback (both electricity and gas) to building users, and encourages engagement with that information through labelling energy patterns, and acting on usage observed by contacting the FM, discussing issues with other building users and through planning behaviour changes.

Study 1 – Not for profit organisation

An early version of the e-Genie platform was deployed at a not for profit organisation in London from April 2016 to January 2017 in order to test the functionality of the system, to engage building users with the building's energy use and to encourage energy saving behaviour. The platform was launched with a lunchtime seminar, providing background about the tool to the building users, and using promotional materials (e.g. e-Genie branded chocolate) in order to incentivise engagement. The functionality of the platform was evaluated through technical monitoring of the data feeds and through ethnographic research. User engagement and impact evaluation were evaluated through ethnographic research, ad hoc user interviews, and via a survey conducted pre deployment of the e-Genie platform and approximately two weeks post deployment.

e-Genie

The e-Genie tool, see Figure 1, has two main sections: front screens which provide energy information feedback (both electricity and gas) and which scroll periodically, and further screens that users reach by 'Taking Action' to support discussing and changing behaviour and reporting energy related faults (see Figure 8).

Temperature calendar

Annotation tool

Always on calendar

Pinboard

Figure 8. Illustrative screen captures of the E-Genie tool.

[36] Costanza, E., Ramchurn, Sarvapali D. and Jennings, N. R. (Sep, 2012) Understanding domestic energy consumption through interactive visualisation: a field study. In Proceedings of the 2012 ACM Conference on Ubiquitous Computing, Pittsburgh, US.
[37] Gollwitzer, P. (1999). Implementation intentions: Strong effects of simple plans. American Psychologist. 54, 493-503.

[38] Bell, B., Toth, N., Little, L., and Smith, M. (2015). Planning to save the planet: Using an online intervention based on implementation intentions to change adolescent self-reported energy-saving behaviour. Environment and Behaviour, 48, 1049-1072.

The energy data screens comprise a Temperature calendar (see previous section), circuit monitoring of electricity with an Annotation tool so users can label usage observed[39], and the Always on calendar which provides information about overnight baseload usage (see previous section). We also provided digital thermometers and thermal imaging camera add-ons for mobile phones that building users could borrow to explore their environment. Support for taking action comprises planning for individual behaviour change by encouraging people to think through and plan their actions more specifically (using implementation intentions) then pledging to make a change, a ‘Pinboard’ discussion space which supports interactions amongst building users, and a direct link to the buildings facilities manager for more straightforward actions.

The implementation of the website was tightly coupled with the organisation’s workspace, visualising data generated by temperature sensors (developed by Wireless Things) placed in spaces around the workspace, and electricity monitors (produced in-house) deployed at the buildings electrical incomers and consumer boards (to capture both aggregate and circuit level electricity consumption). Data from these sensors was fed to data hubs (Raspberry Pis) on the Local Area Network that periodically pushed the data to a remote data store, which was accessed and visualised by the e-Genie website.

Key Findings

In-depth use of the e-Genie system overall was limited (N = 10; approximately 17% of building users). Whilst many occupants did try interacting with e-Genie, many of them did not go further than the front screens. The system requirement for users to log in to use certain aspects may have put people off exploring the tool. Observations and interviews suggest users found the system offered too much information and too little guidance. There was a general uncertainty about how the system was supposed to be used. This suggests that the purpose, or use case, needs to be better defined. Where people did engage it tended to be through the prism of what is most tractable to them, in this case, thermal comfort complaints. Thermal cameras and thermometers were only used by a small proportion of building users, suggesting that there is more work to be done on linking the supporting tech to the software. Occupants here (like many other buildings) have little direct control over their use of electricity (e.g., laptop or monitor already automatically turn off) and heating at work, indicating that e-Genie needs to do a better job of supporting the user to recognise where they can make a difference.

This deployment also enabled the testing of the robustness of the data collection infrastructure, the ease with which the situated tablets could be kept operational over complete working weeks, and the extent to which we could monitor the deployment remotely. Key weaknesses in the infrastructure were highlighted: wifi network dropouts; ‘freezing’ of data hubs; and server issues.

Study 2 - Council site

A further version of e-Genie was deployed at a council site from January 2017 to June 2017 in order to further test system functionality as well as to engage building users with the building’s energy use and energy saving behaviour. The platform was launched with a stall in the canteen and the installation of tablets in kitchen areas on 6 floors of the building, with ~600 occupants out of ~900 in the building overall (the building has 9 floors in total). The stall in the canteen provided building users with further information about the e-genie tool through direct contact with the researchers and offered snacks (pastrys and cupcakes) in order to promote engagement. During the deployment, four workshops were run with members of staff in order to assess the organisational energy context, in order to engage staff, and in order to develop ideas for further policy changes that could be enacted locally in order to improve energy efficiencies. Ideas generated fed into the pledging section of the e-Genie tool. The functionality of the platform was evaluated through a pre and post survey (approximately two weeks after deployment), through monitoring of the tool engagement, and through ethnographic research.

e-Genie developments

We developed the e-Genie tool further prior to the second trial deployment. Specifically we removed the annotation tool given concerns that in it’s current form it was difficult to understand. We also consolidated and shortened the pledge tool sequence, adjusted the means of navigating the tool, removed the ability to privately contact the FM, removed the necessity to ‘Log in’, and improved usability with functional adjustments.

The pledge tool was consolidated by removing the electricity and heating tabs (and displaying these options in the same space), combining and shortening the initial instruction pages, and adding a drag and drop functionality so that participants could create their own pledges. The navigation of the tool was developed so that the user was able to switch between screens using tabs rather than arrows and added a screen so that when the user clicked on the button labelled ‘Do something’, this linked to an overview screen from which the Pinboard, and Pledge tool could be accessed. Usability was also improved by adding labels to the temperature calendar indicating the current month, highlighting the current day on the temperature calendar, flipping the calendar so it read left to right chronologically, reducing the amount of space dedicated to posts on the Pinboard and including a ‘More’ button to view the additional text when posts were long.

[39] Costanza, E., Ramchurn, S., Jennings, N. (2012). Understanding domestic energy consumption through interactive visualisation: a field study. In Proceedings ACM Ubicomp ‘12.

Key Findings

Building user engagement with e-Genie was considerably higher during the second trial, suggesting the alterations made following the first deployment were successful. Direct comparison is difficult due to the different circumstances of the two sites but, here for example, the Pinboard received 71 comments during the first 6 weeks of deployment, compared to only 5 or 6 comments in the previous deployment. Unfortunately, the value of this space for improving communications between staff and FM was hampered by limited engagement by the latter. It is clear that further success relies on finding ways to strengthen FM engagement. Improvements to e-Genie could support this - for example the Pinboard gave no special status to FM comments, so even if they had been more common they might not have been easy to find.

Survey results (N = 77) revealed that mean individual energy behaviour intentions (e.g. switching off equipment) did not change significantly over the first two week period that e-Genie was installed but that social energy behaviour intentions (e.g. discussing energy saving measures with colleagues) increased significantly (see Figure 9). Concerns about saving energy at work also increased significantly after two weeks of experiencing the e-Genie system however instrumentality (perceptions that your actions can have an impact) did not differ, see Figure 10.

In particular we surmise that the installation of e-Genie may have helped to raise awareness of energy saving issues. Lack of effects on individual behaviour intentions may, at least in part, relate to a lack of opportunities for individual behaviour in a shared office space.

Open-ended questions were also used to examine what people liked and did not like about e-Genie, how they thought e-Genie could be improved, and reasons why they did not pledge to change their behaviour if they did not do so. With regards to what was liked, people particularly reported that they found the visualisations and information useful, and that the tool encouraged communication and discussions. Notably, it was highlighted that the installation of e-Genie demonstrated that the management take related issues seriously.

Responses relating to why e-Genie was not liked and what could be improved primarily focused on increasing the reach of the tool in terms of what data it collected, improving the usability of the system (in particular making it easier to comment, navigate the system and to improve access on mobile devices), and remedying technical issues. Respondents also commented that they would like more local control over their energy use and they were keen to see action taken by management on issues raised.

The pinboard section of the e-Genie tool was also successful in gathering feedback from building users. In particular insights on thermal comfort in different sections of the building and on different floors were gained and dialogue regarding the operation of the heating and cooling within the building improved understanding of the issues that facilities managers face by building users. Overall, contributions from the workshops and e-Genie suggest that improved communications between building users and facilities management on all aspects of building management was, and would continue to be, beneficial.

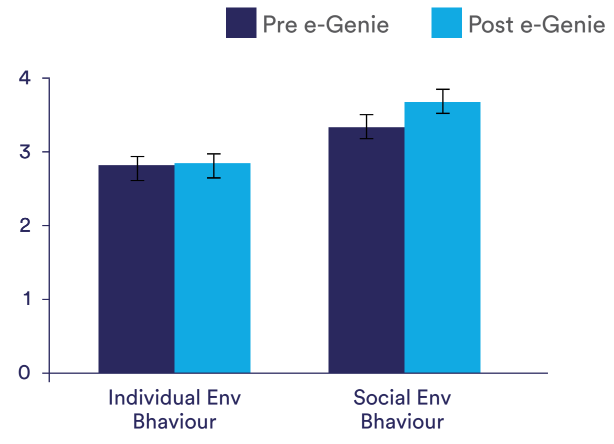


Figure 9. Behavioural intentions Pre and Post the e-Genie installation. The error bars represent standard errors.

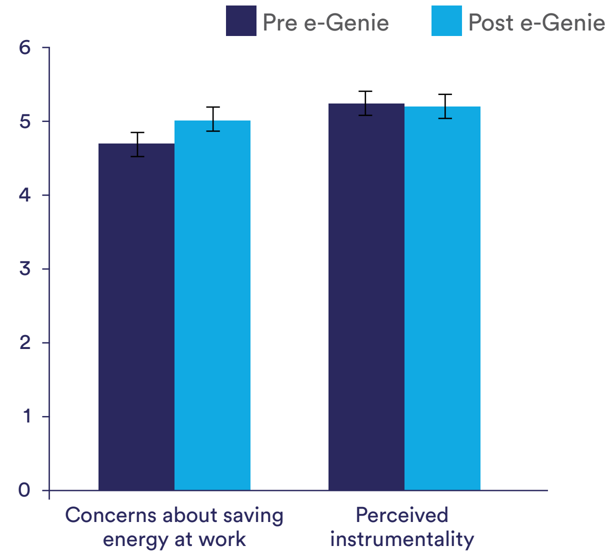


Figure 10. Perceptions of Concern and Instrumentality Pre and Post the e-Genie installation. The error bars represent standard errors.

Conclusions

Our deployments of e-Genie indicate that digital energy visualisations are liked and useful where there are clear issues, or a clear use case, relating to energy. Future research could consider developing use cases for users where issues don't exist, e.g. energy challenges, in order to engage building users with energy savings; it is likely that incentivisation would be necessary here.

The e-Genie tool itself requires further development, particularly around its user interface and around the technical systems underpinning the visualisations. The functions that it serves appear to be liked, in particular the provision of information and the facilitation of discussion. Further integration of the e-Genie tool with facilities management and workplace policies is likely to be beneficial given users, positive reactions to energy leadership and the desire to see actions taken on issues raised. There is a limit to what software alone can achieve here however, **key actors within the organisation must also be committed and resourced to adapt existing processes to support new technological innovations.** Specifically here, we found that staff need an opportunity to talk through e-Genie data and consider potential actions in relation to their workplace context; our workshops were used to provide this opportunity. We recommend the use of e-Genie as a tool that sits within a toolkit of complementary engagement and data collection techniques (see Toolkit section).

Importantly we found that the e-Genie tool appears to have had an impact, both on concerns about saving energy and on intentions to undertake social energy saving behaviours at work. We suggest that **interactive energy visualisations such as e-Genie can be successful in reducing energy use in the workplace**. This kind of tool may also be useful for supporting other energy saving goals in the workplace for example shifting energy usage away from peak usage times, and future research should further investigate these possibilities.

Conclusions and Recommendations

6

Conclusions and Recommendations

Converging data from different parts of the Ctech project has provided us with broader insights into energy use within the workplace and how best to engage people to reduce that usage. We have reflected on the current state of energy management in workplaces, digital energy technologies, relevant energy policy and building user responses in order to reflect on the future of building energy management and the potential that digital technologies have in managing energy more efficiently.

Communication is a key element of energy management. When we brought different building users and stakeholders together in workshops to discuss energy issues in the building we saw immediate benefits and on a few occasions immediate process changes resulting in energy savings. Evaluation of e-Genie also specifically highlighted the utility of the Pinboard discussion tool in supporting and facilitating discussions around energy; and that this was popular amongst building users, currently often excluded from decisions about their working environment. In ethnographic research we observed that there were often complaints of a lack of understanding, both by building users of the energy policies and systems in place, and by Facility and Energy Managers of the context in which energy use was situated.

We conclude that communication around energy systems, and the context of energy use is an important part of energy management and should be explicitly considered and supported. Communication should be bi-directional so that building users can communicate ideas and issues to Facility managers with Facility management also communicating on current problems and new policies and solutions being developed. Increased communications may also help to make use of building users as a source of information, provide building users with a means of asserting some kind of control over their energy use, and to discuss the legitimacy of energy use where necessary. Each of these aspects is elaborated below.

Key Conclusions

Communication is a key element of energy management – increased communication around energy systems and the context of energy use is an important aspect of energy management that should be explicitly supported. Communication should be bidirectional between Facility managers and building users.

Organisational goals and leadership matters – Building users respond positively to signals that management take energy issues seriously. Energy technology installations can be used as a way of delivering and informing energy policy initiatives.

We need more understanding of energy data, not more data – Energy data is often currently underused for energy efficiencies. Digital technologies and visualisations can support operations by focusing attention (for example, on errors or unexpected usage), by providing forecasted data, and potentially by automating some optimisation functions.

Technological interventions must have a clear purpose and use case – Technology on it's own can have little impact, these should be tailored to the organizational context and engage building users either with current workplace energy issues or with alternative fun goals.

Facilities management is often characterised by an absence of engagement with building users. There is a common narrative observed amongst Facilities management that building users are 'whiners' and always complaining; this is accompanied by a lack of engagement with the issues that are raised, perhaps unsurprisingly given complaints are often conflicting and facilities management often do not have the time, or means to deal with these. However, a consequence of this lack of engagement is that the building users may become disenfranchised, an impediment to creating sustainable workplaces rather than a catalyst. Such workforces do not report back important energy issues that could improve current energy management and do not feel any sense of responsibility over their energy use because they not given a reason to.

Building users are an important source of information. People who are using and developing operations which use energy in a company are best placed to observe where energy savings can be made. There is a key disconnect between those who use energy and those who manage energy. In practice monitoring is often delegated to sensors, which are then often remotely monitored. Unfortunately we observe that sensors have many limitations. They may be broken, be poorly calibrated, or be poorly sited due to clumsy installation or alterations to the space around them. When working as intended, the data they generate is only valuable as long as it is analysed along with appropriate situational knowledge. These factors can result in suboptimal conditions, and subsequent mistrust and negativity in communications.

Building users often have little control over local energy use. Staff in the workplaces that we engaged with repeatedly highlighted that they were frustrated by a lack of local control over their energy use. Indeed digital technologies providing energy feedback has the potential to exacerbate this feeling in making local users hyper-aware of their energy use without any means of acting on the problems that they observe.

People care about the legitimacy of energy use. In practice, regardless of building design and optimal energy system functioning, people have different individual needs with regards to energy use. In discussing energy it is clear that people have strong feelings about where energy use is legitimate or illegitimate. Where people overuse energy because they legitimately need to for work purposes or health reasons, there is a strong sense of justice, and we find that colleagues are even willing to make greater efforts to reduce their own energy use to allow this increased usage. Communicating, and allowing communications about, the context of energy use may therefore reduce conflict and misunderstandings around the provision of energy data alone. In practice, individual tailoring requires additional local control and measures in order to enable this and therefore energy systems and initiatives would ideally be flexible in order to cope with the heterogeneity of building users and the dynamic nature of building users in the work environment. This point also speaks against the potential use of individual level incentives or punishments in motivating people to engage with energy savings because different people have different needs and this will necessarily exclude many people from engaging with such mechanisms.

Organisational goals and leadership matters. We found that evaluative feedback around e-Genie highlighted that intervention itself was perceived as a sign that the management took energy issues seriously and this was felt to be a real positive. Our systematic review of energy interventions in the workplace also highlighted strong leadership on energy issues as a key determinant of a successful intervention. Furthermore, a notable result within our exploration of motivations for energy saving within the workplace was that building users didn't undertake energy saving for reputation building reasons unless they felt that organisations value energy saving. Indeed when organisations did not value energy saving, where people rated reputation building as important, they were less likely to undertake energy saving behaviour. We conclude that leadership on energy saving and efficiency goals is really important to motivate the rest of the workforce to care.

Organisational culture will affect motivations driving energy saving behaviour. We found that relationships between motivations to save energy and intentions to save energy differed between organisations. Energy saving intentions are related to environmental concerns, motivations to help organisational image and finances, and reluctant altruism (the idea that you better act because no one else will), all of which are likely to differ between organisations. Whether the company brand or image is perceived to be important may affect how relevant organisational image motivations are for example. People's sense of organisational community may also affect perceived incentives to save energy. In not for profit organisations particularly, staff may link financial costs from energy wastage to being a detriment to the social good, a waste of public funds, and potentially to jobs cuts.

Organisational policy should support interventions. Technological interventions will be most effective if integrated within organisational policy so that there are clear mechanisms in place and responsibilities assigned to support its use, and to enable organisational change and policy development based on issues highlighted. Furthermore, we found that social interactions around energy feedback systems could result in unintended consequences and policy had a role here in making sure that this did not result in animosity or increases in energy use. Where energy use is shared, it is likely that in many cases this will be unequal. Where unequal energy use is perceived as unfair our studies indicate that the likely reaction is anger and/or increases in personal energy use. Institutional regulations are the preferred response by employees to energy wastage in order to maintain cooperation and legitimacy of energy use should be discussed and defined in order to avoid discord.

Energy technology installations can be a way of influencing culture. As noted, there was some evidence that building users viewed e-Genie installations as a sign that the management valued energy savings and this was seen as a positive signal to focus on energy saving behaviour. Indeed, our evaluations of e-Genie indicated that after two weeks of having e-Genie installed in the workplace, building users indicated that they were more concerned about saving energy at work and that their behavioural intentions to undertake social energy saving actions (e.g. discuss issues with colleagues, report energy faults) had increased. Importantly technology may be able to play a key role in future cultural shifts, for example demand shifting to reduce energy usage at peak times. There is an increasing move towards workplaces attempting to shift energy use. At one of our sites studies, 'red band' charges between 4 and 7pm were over 11% of the final energy bill, providing opportunities for large cost savings if energy demand can be shifted. We note that meeting demand through automation of heating turn downs or switching off will also require building user acceptance to be effective. Technology may have a role in creating coordinated action, communicating current organisational policies, and providing signals for behaviour changes.

We need more understanding of energy data, not more data. The amount of energy data available to facilities management is increasing all the time. We have frequently found that facilities management have more data than they can process, indeed the quantity of data risks becoming an impediment to effective action. Accordingly, building energy management systems are underused for considering energy efficiencies. Facilities managers dealing with the data also often appeared to be under resourced in terms of time and skills training. We highlight that there may be an opportunity here for digital technologies to support operations in identifying energy problems ahead of time, in providing forecasted data to identify the cost effectiveness of proposed new energy policies and initiatives, and also in identifying, and even automating, some of the potential energy optimisation work.

Feedback visualisations can focus attention. There is a huge range of energy feedback visualisations available and most are not well understood. We propose that feedback displays should be designed to help users identify errors and unexpected energy usage. Building users may naturally identify the energy usage that they are responsible for but this may often be the usage that they are least able to change. Discussions around identifying the energy usage that people do not notice and understand may however be relatively easier in identifying usage that can be more easily reduced (e.g. out of hours usage) without any loss of comfort or impact on current procedures.

Privacy concerns are an important issue but employees are often willing to share data. Privacy concerns around energy data are an issue often highlighted however it did not spontaneously arise as an issue in any of our deployments. This may be a feature of the types of studies that we conducted and the relative lack of disaggregation of energy data included in our analyses, it may be because people do not understand or consider the potential insights that energy data holds in relation to exposing their behaviour, or it may be because people accept that they are monitored in their workplaces. In one study (Idlewars), in which energy data exposed the amount of time employees spent working at their computers, privacy issues and energy data sharing was purposely probed and participants were happy to share their data. We conclude that the current levels of disaggregation possible for energy data with standard building energy management systems do not concern most building users with regards to privacy issues and when done sensitively that further levels of disaggregation are also likely to be accepted.

Technological interventions must have a clear purpose and use case. We have repeatedly observed, both within our own deployments and within our systematic review of energy saving interventions, that technology deployed on its own often has little impact. We found that our initial deployment of e-Genie garnered little engagement from building users and feedback here indicated in part that the purpose of the tool was not understood; people saw little reason for using the tool. In a much more specific investigation, we found that cost information was sometimes considered to be demotivational with regards to energy saving, but the advantages of environmental information compared to cost information actually disappeared when units were equalised and the size of the numbers provided to users were more similar. This does highlight the importance of instrumentality for energy saving however - the idea that your actions have an important impact.

In order to be engaged with by building users and accepted, technological interventions must have a clear purpose, should be tailored to the current organisational context, and engage building users with the everyday issues that they face around energy use in terms that are important to them and demonstrate that their actions have an important impact. When people are focused on their core work issues, it will be difficult and probably undesirable (long term at least, though we acknowledge the benefits of disruptive technologies in the short term) to interrupt workflow. Interventions should therefore, where possible, sit within existing systems (e.g. online portals) and within natural dwell spaces (e.g. kitchens).

Technological interventions should be dynamic and supported over time. We found that after a period of time engaging with e-Genie, users started to question the data and the purpose in more depth. Users expected that the issues that they raised would be acted on and in cases where this did not happen then there was disillusionment with the purpose of the tool. Indeed, we think it clear that new technological interventions do have a novelty effect and to continue engaging users, the technology would have to be continually changed and supported.

Digital interventions should support collective as well as individual responses. Whilst there undoubtedly are - depending on the work and the space in which it occurs - opportunities for individuals to reduce their own energy use in the workplace, they are limited, particularly in modern offices with centralised controls. Individuals can though affect change on organisational-level energy uses, such as heating, ventilation and lighting, if they are empowered to input into the management process. e-Genie sought to support this through the combination of information and discussion tools.

It is possible to create alternative fun goals. A focus on tailoring interventions to the situation does beg the question - what if there are no key energy issues that people are concerned about? We propose that it is also possible to create new, fun, goals for building users. Our Idlewars deployment which engaged building users in a game which involved busting each other's computer monitors when left idle, rather than put in an energy saving mode was highly successful in engaging people with energy saving issues. This game provided a competitive scenario which engaged building users, encouraged communication, and created discussion around energy issues.

An Energy Management Toolkit for the Workplace

7

An Energy Management Toolkit for the Workplace

The Ctech project has developed a "toolkit", a set of processes, applications, and guidance which have been developed from the research findings and are intended to be used in real life contexts as part of the project's legacy. The tools are integrated - they work together but can also be used selectively as standalone elements. The idea has been to create a flexible resource that facilities managers can choose from depending on their particular organisational needs. The toolkit has five main elements: a Workplace Energy Audit Tool; energy workshop templates and plans; the e-genie web application for visualising and engaging people with energy and energy reduction; guidance on designing energy engagement communications; and a digest of academic papers produced within the C-tech project. The toolkit will be hosted as a free to use resource on the CSE website. We elaborate on each below.

Workplace Energy Audit Tool

The Workplace Energy Audit Tool provides a ready means of creating an inventory of equipment in the space and the savings that could result from using energy efficient alternatives. Unlike standard auditing tools which simply compile an inventory of equipment, current notional hours of daily usages and the associated specifications (power ratings etc) the tool is also designed to record the social processes which influenced how equipment is actually used in practice. It does this through providing sets of prompts which guide the auditor to uncover issues of control of equipment, ownership of space, guerilla and forbidden energy using practices (such as the often-found under desk fan heater) and formal and informal hierarchies and group allegiances. The evidence gathered using the tool feeds directly into the workshops outlined below.

An additional component of the audit tool is thermal imaging equipment that can be attached to a smart-phone. In our deployments we have found the use of thermal imaging to be highly engaging. The toolkit contains guidance on use of thermal images taken using the smart phone application .

The e-Genie tool (see previous section)

The e-Genie tool is a web application designed to engage building users with the energy system and use within the building and support users to take action to better manage energy use. It is a modular application, in that different functions can be selected as appropriate for the context in which it is deployed. The tools key functions are to:

a) increase energy literacy by providing feedback on the temperature and electricity use in the space;

b) provide of an internal communication platform through the pin board and messaging features;

c) encourage behavioural pledges to undertake specific energy related goals and to support pledge achievement through planning.

The e-genie code will be open sourced and instructions for setting up the system and troubleshooting deployments will be made available in a technical manual.

Workshop templates and resources

The workshops provide an opportunity to collectively diagnose energy management issues in the workplace, to work through the data generated by the e-Genie tool and to develop solutions for improving comfort and efficiency which recognise the need for staff involvement and engagement. They have been designed using insights from the C-tech research, for example there are specific exercises to draw out the formal and informal practices around heating and cooling controls, to map ownership of space and comfort and to systematically develop energy management strategies for the organisation. The workshops have been designed to run for around one hour so that they can be accommodated within a lunchtime.

Workshops are also modular. Users can take elements from them and recombine in an order that suits their requirements however the general principle is that exercises in the workshops are divided into those related to thermal comfort and power use and are sequenced so that participants begin by being introduced to the e-Genie tool, perform a mapping of energy issues in the workplace, then work through issues of control of energy use and apportionment, see Figure 10⁰. In the final workshop the work of the previous workshops is brought together, solutions are identified and prioritised before finally being reviewed using the Capability Opportunity and Motivation Behaviour change (COM-B) framework10 to work out the practical next steps for improved energy management in the workplace.

There are four workshops altogether:

Workshop 1 involves exercises that:

- Introduce e-genie
- Map energy consuming activities in their workspace
- Map power consuming devices in their workspace
- Map winter and summer comfort in the space (see Figure 11)
- Map workplaces practices and technologies needed to be comfortable

Workshop 2 involves exercises that:

- Map quantity and type of of energy use to different activities
- Allocate ownership and control of the energy consuming activity

Workshop 3 exercises:

- To identify some more energy efficient ways of doing things
- To think through what is needed to make the energy efficient alternatives happen

Workshop 4 exercises:

- To identify which behaviours and practices we should focus on in an energy management strategy
- To develop the energy management strategy

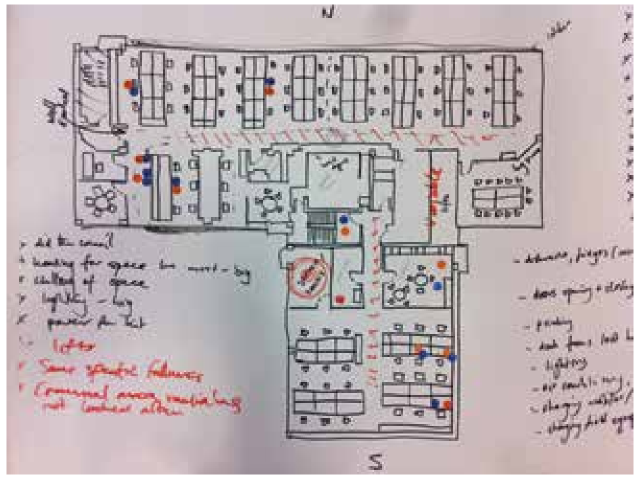


Figure 11. Example of a thermal comfort map developed as part of the workshops

Guidance on designing energy engagement communications

Guidance on the presentation of information about energy consumption and saving to building users in a workplace. This reviews the current academic thinking in this field and draws on C-tech research into the psychology of environmental and energy related behaviours in the workplace. We anticipate this guidance to be used in the preparation of information campaigns including the design of posters and electronic messaging.

C-tech digest

The toolkit also includes a digest of the research papers produced as part of the Ctech project written with a lay audience in mind. This will give toolkit users an overview of the theory underlying the development of the various toolkit elements and pointers to further reading if desired.

Project Outputs

Staddon, S., Cycil, C., Goulden, M., Leygue, C. and Spence, A. (2016). Intervening to Change Behaviour and Save Energy in the Workplace: A Systematic Review of Available Evidence. Energy Research and Social Science. 17, 30-51.

Costanza, E., B. Bedwell, M. Jewell, J. Colley, and T. Rodden (2016). 'A bit like British Weather, I Suppose' Design and Evaluation of the Temperature Calendar. In Proceedings of the 34th Annual ACM Conference on Human Factors in Computing Systems, CHI '16, New York, NY, USA. ACM.

Bedwell, B., E. Costanza, and M. Jewell (2016). Understanding energy consumption at work: Learning from arrow hill. In Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work & Social Computing, CSCW '16, New York, NY, USA. ACM. doi:10.1145/2818048.2819993

Kefalidou, G., Skatova, A., Shipp, V. and Bedwell, B. (2015). The Role of Self-Reflection in Sustainability. In Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct (MobileHCI '15). ACM, New York, NY, USA, 1030-1033. DOI=http://dx.doi.org/10.1145/2786567.2795398

Jewell, M. O., Costanza, E., Kittley-Davies J. (2015). Connecting the Things to the Internet: An Evaluation of Four Configuration Strategies for Wi-Fi Devices with Minimal User Interfaces. In Proc. UbiComp '15.

Tolias, E. Costanza, E., Rogers, A., Bedwell, B., and Banks, N. (2015). Idlewars: an Evaluation of a Pervasive Game to Promote Sustainable Behaviour in the Workplace. Int Conf on Entertainment Computing.

Demski, C., Butler, C., Parkhill, K. Spence, A., and Pidgeon, N. (2015). Public values for energy system change. Global Environmental Change. 34, 59-69.

Goulden, M. and Spence, A. (2015). Caught in the Middle: The Role of the Facilities Manager in Organisational Energy Use. Energy Policy. 85, 280-287.

Xenias, D. Axon, C. J., Whitmarsh, L., Connor, P. M., Balta-Marsh, N., and Spence, A. (2015). UK Smart Grid development: an expert assessment of the benefits, pitfalls and functions. Renewable Energy. 81, 89-102.

Butler, C., Demski, C., Parkhill, K., Pidgeon, N. and Spence, A. (2015). Public Values for Energy Futures: Framing, Indeterminacy and Policy Making. Energy Policy, 87, 665-672.

Spence, A., Demski, C., Butler, C., Parkhill, K., and Pidgeon, N. (2015). Public perceptions of demand side management and a smarter energy future. Nature Climate Change. 5, 550-554.

Bedwell, B., Leygue, C., Goulden, M., McAuley, D., Colley, J., Ferguson, E., Banks, N. and Spence, A. (2014). Apportioning energy consumption in the workplace: a review of issues in using metering data to motivate staff to save energy. Technology Analysis & Strategic Management. Special Issue of Smart Metering Technology & Society. 1196-1211. [Also featured in a cross journal special collection of articles on the Psychology of Work.]

Leygue, C., Ferguson, E., Skatova, A., and Spence, A. (2014). Energy sharing and energy feedback: Affective and behavioural reactions to communal energy displays. Frontiers in Energy Research, section Energy Systems and Policy.

Goulden, M., Bedwell., B., Rennick-Egglestone, S., Rodden, T., and Spence, A. (2014). Smart Grids, Smart users? The Role of the User in Demand Side Management. Energy Research & Social Science, 2, 21-29.

Spence, A., Leygue, C., Bedwell, B. and O'Malley (2014). Engaging with energy reduction: Does a climate change frame have the potential for achieving broader sustainable behaviour? Journal of Environmental Psychology. 38, 17-28.

Colley, J. A., Bedwell, B., Crabtree, A. and Rodden, T. (2013). Exploring Reactions to Widespread Energy Monitoring. Human-Computer Interaction – INTERACT, 8120, 91-108.

Appendix

Appendix

Table 1: Motivations to Save Energy at Work Scale

Exploratory factor analysis (oblique rotation) factors and items (factor loadings are indicated between brackets) *Note. Items in italic were not included in the final factor*	Items included in Study 2
Helping one's organization's image motivation (α = .83)	
Because I feel pride in the organization (.74)	✔
Because I am committed to the company (.69)	✔
To help my organization achieve a "greener" image (.48)	✔
Reputation Building in one's organization motivation (α = .86)	
Because my colleagues would be more friendly towards me (.77)	✔
Because people I like want me to (.68)	✔
Because my colleagues do (.67)	✔
Because I don't want to appear irresponsible to my colleagues (.67)	✔
Because I can mention it to my co-workers to impress them (.65)	✔
Because my actions may be rewarded by superiors (.60)	✔
Because I think that demonstrating commitment to my organization will be recognized (.50)	✔
Because it will help me get over any guilt I feel about not saving enough energy elsewhere (.38)	✘
Because people I know place a high value on environmental issues (.37)	✘
Environmental concern motivation (α = .85)	
Because I am concerned about climate change (.95)	✔
Because I feel worried about the environment (.90)	✔
Because I am concerned with energy security, i.e. the extent to which supplies may run out or become unreliable (.73)	✔
Because it would help my children in the future (.54)	✔
If I do, it will encourage others to do the same (.33)	✘
Helping one's organization's finance motivation (α = .91)	
To help my organization save money on energy costs (.91)	✔
Because it would make my company save money (.89)	✔
Warm-glow motivation (α = .85)	
Because I'd feel good about myself (.89)	✔
Because I'd feel proud of myself (.84)	✔
Because I would find it personally rewarding (.78)	✔
Because it would seem like the right thing to do (.40)	✔
Because I like to maintain an environmentally friendly image (.29)	✘
Reluctant altruism (α = .73)	
Because if other people don't save energy at work, I feel I have to (.99)	✔
Because I can't trust other people to save energy at work (.47)	✔
Because someone has to do it (.35)	✔

Contact details:

Alexa Spence

School of Psychology,
University Park,
University of Nottingham,
Nottingham, NG72RD

E: **alexa.spence@nottingham.ac.uk**
W: **www.energyforchange.ac.uk**