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An Energy Management Toolkit for the Workplace

A legacy project of the Ctech project

About Ctech

Ctech was a large multidisciplinary programme of research that explored interactive shared energy feedback and community engagement in the workplace. It involved in-depth exploration of multi-occupancy workplace buildings with an extensive set of studies and deployments which provided great insights into energy perceptions, engagement, management and the potential for digital tools in this space. This toolkit is a legacy of the project. It collects together the research instruments and tools and provides guidance on their use so that Ctech project findings can be used in energy management in real world settings.

Ctech was funded through the EPSRC and led by Alexa Spence at Horizon Digital Economy Research.

About Ctech partners

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.

1 The Ctech Toolkit

The Ctech project has developed a “toolkit”; a set of processes, applications and guidance which have been developed from research findings from the Ctech project and are intended to be used in real life contexts as part of the project’s legacy.

The toolkit aims to give building users new insights into how energy is used in the workplace and to provide facilities staff with the means to engage with staff more effectively as part of wider energy management practices.

This document is to be used as a guide to the toolkit. It explains the purpose of the tools and how they should be deployed and used. The actual tools are separate files and resources, found as electronic resources accompanying this document or via hyperlink as files on the Cloud. The toolkit has five main elements:

- the e-Genie web application for visualising and engaging people with energy use;
- a workplace energy audit tool;
- energy workshop templates and plans;
- guidance on designing energy engagement communications; and
- a digest of academic papers produced within the C-tech project.

The tools were developed and successfully deployed in 5 settings:

1. Centre for Sustainable Energy Office’s in Bristol
2. A large multi storey office building used by Nottingham City Council
3. The Oncology building at University Hospital Bristol
4. The libraries managed by Wiltshire County Council
5. The offices of Digital Catapult in central London

Hence the toolkit can be deployed in most workplaces however it is primarily designed with large offices in mind.

1.1 Expected benefits

Benefits of the toolkit are:

- Increase in energy literacy of staff and facilities management – the tools allow new insight into what consumes energy at what time,
- Increased engagement with energy use as an issue and the need to use it carefully. Using the toolkit allows building users to understand the "story" of energy use in their building,
- A process for co-designing (with building users) a behaviour change and energy management strategy,
- Guidance on the design of supporting materials based on the social psychology of the workplace,
- Providing a further impetus for staff to undertake small measures in the workplace through e.g. the pledging tool.

A template "offer" note for organisations which explains the deployment process and the benefits to the organisation is shown in Appendix 2: Example of the offer document.

Figure 1: the toolkit has processes within it for mapping comfort in the office space and then co-developing strategies for improving comfort while saving energy

Ctech evaluated the impacts of various components of the toolkit (see research digest section of this document). Evaluation of the deployment at Nottingham City Council offices indicated that people were significantly more concerned about energy issues and reported engaging more in social energy behaviour after about two weeks of e-Genie being installed. In addition objective measures of electricity use decreased over the same period, and continued decreasing over subsequent weeks.

This suggests that occupant-facing energy-feedback visualisations can be successful in reducing energy use in the workplace a, supporting social energy behaviour in the workplace is likely to be a useful direction for promoting action[1].

1.2 How the toolkit tools work together

The heart of the toolkit is the **e-Genie application**. This is a software application that gives energy and temperature data visualisations to building occupants on dedicated screens. It also has functions to allow staff to make pledges to change their behaviours and creates a pin board space where energy issues can be identified and possible solutions crowdsourced.

From evaluation of the deployments of e-Genie it was clear that simply providing staff and FMs with visualisations of energy and temperature was insufficient to prompt behaviour change. Staff needed an opportunity to talk through the energy data, to myth bust and begin to understand the "story" of energy use in their workplace. Accordingly a set of supporting workshops and other materials were developed as follows.

Workshop templates guide users through a set of exercises which are designed to uncover how energy is used in the space, issues of comfort and control and to work towards behavioural and technical solutions. The information from e-Genie can feed directly into the workshop discussions. Three workshops were developed designed to be delivered in sequence:

1. Workshop 1. Introduction and mapping. Staff are introduced to the e-Genie toolkit. They are then asked to map activities in the workspace, comfort levels and the technologies used to achieve comfort within their building.
2. Workshop 2 Apportionment. This workshop is about using data to work out what and who consumes energy. It also aims to identify who has control or influence over energy consuming practices.
3. Workshop 3. Causality and Strategy**.** 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 (COM-B) behaviour change framework.

E-Genie, in tandem with the workshops increases staff energy literacy and engagement with energy use and creates the buy-in needed for successful behaviour change interventions.

The **energy audit tool** is also designed to generate information about how energy is used within the organisation (the various end uses – heating, lighting etc) but also to provide insight into the way that it is used – to consider the energy management and behavioural dimensions. It asks questions such as who has control of heating settings, is there scope for shifting some end uses out of peak times, why do staff control the lighting as they do. This information also feeds into the workshopping process.

The energy audit tool has also been designed so that a technically confident facilities manager can benchmark the performance of their office and also explore the energy and carbon saving potential of various measures. Where measures are found to hold promise they too can be tested in the workshopping process.

[1] Digital energy visualizations in the workplace: the e-Genie tool. Spence et al (2018) Building Research & Information, 46:3, 272-283. Available at: www.tandfonline.com/doi/abs/10.1080/09613218.2018.1409569

Energy management options and issues for consideration can also be captured by e-Genie's **pinboard**. As staff identify faults or have suggestions for improvements the pinboard offers a place where these can be recorded. Facilities managers are able to view the pinboard and respond. Issues can be brought into the workshop process and solutions explored.

Engagement with staff also can be improved by paying attention to **design of communications materials** – notices, emails etc can all be designed using principles drawn from social psychology. The toolkit contains some guidance on this drawn from the research. E-genie also supports a pledging tool. The energy efficiency measures that have been explored in the workshops can be used to provide the options offered by the **pledging tool**.

Finally, for those who wish to read further the toolkit contains a **digest of the research papers** generated by the Ctech project. This research and guidance is intended for use by facilities managers in the design of awareness raising and communications strategy as part of a wider behaviour change programme.

Once interventions have been designed and implemented their effects can be monitored using the egenie tools. For example, changes in temperature in a space can be identified. This information should then be fed back to staff to support behavioural change.

These relationships between the various elements of the toolkits are shown in Figure 2.

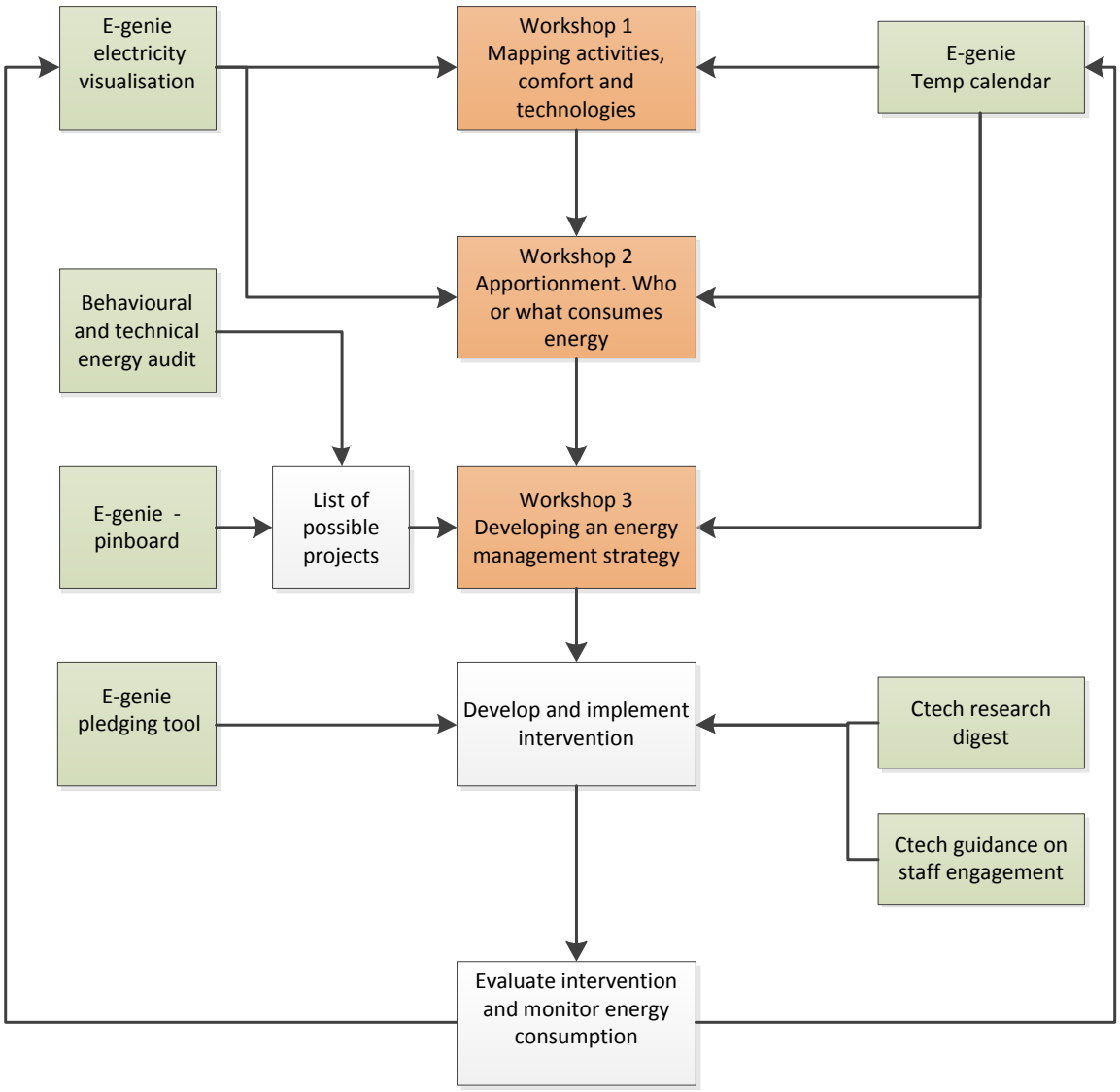


Figure 2: The relationships between the various elements of the Ctech toolkit

1.3 Deployment process

A standard deployment of the toolkit usually has the following sequence:

1. Around two weeks before deployment, we propose 2 team members will come on-site for one or two days to understand the workplace's infrastructure and practices. It would be useful for them to meet with the Facilities Manager to ensure we tailor the intervention in a way which is useful to them, and observe the workplace to understand how energy is currently managed and used. They will seek to conduct short interviews with willing staff about current energy use.
2. On the day of deployment we will install e-Genie and will aim to engage as many of your staff as possible by running a seminar to communicate the project to staff during a staff meeting, and by distributing promotional material to raise awareness of e-Genie and the Ctech platform.

3. Once e-Genie is deployed staff will be able to interact with the installed touch screens to explore our visualisations of your workplace's energy consumption, create energy-saving goals and discuss ways to reduce energy use. During this time, we will spend time observing interactions with and around e-Genie, and take appropriate opportunities to discuss the impact of the system with staff.
4. Conduct workshops. We will also work with facilities managers to organise the sequence of 3 workshops with staff (see above) which draw on e-genie information and aim to arrive at new energy management strategies which are grounded in the realities of staff behaviours and facilities managers' needs.
5. Later in the deployment, (approximately two weeks after initial deployment) we will email a short follow-up questionnaire to already participating staff to evaluate the impact of e-Genie on their energy-related attitudes and behaviour.

1.4 Skills and resources needed for deployment of the toolkit

A number of skills and resources are needed for deployment.

1.4.1 Technical skills for deployment of egenie

To produce the visualisations in the energy consumption dashboard and temperature calendar, e-Genie needs to capture data about the energy consumption of the building and resulting temperature in different parts of the building. This data is stored on the e-Genie server, allowing the organisation to access it via standard web-browsers on workplace computers, and on tablets supplied by C-tech that can be placed strategically around the building. The hardware needs of egenie are:

- Wireless temperature sensors with long life batteries
- Electricity monitoring board with CT clamps for clipping round circuits on the distribution board. At present we have the IotaWatt board which can monitor 14 circuits. This sends data via WiFi to the egenie servers.
- Hubs to receive data from sensors and send to egenie servers
- Tablet computers to display the egenie webpages in circulation spaces such as kitchenettes

CSE is in possession of all the hardware requirements of egenie. However, setting up the sensors to capture energy and temperature data, configuring local or cloud servers to store the data and then the egenie visualisation tools to access it is not a one click operation. It requires a software technician. At CSE, Tom Hinton and Mark Gibbons have both been trained to perform the egenie setup. The code has also been documented by Mike Jewell[2] (see the GitHub repository of the codebase at https://github.com/cse-bristol/312-e-Genie-deployment). Mike also wrote much of the code.

1.4.2 Delivering the workshops

The workshops have been designed to be delivered by a confident facilities manager. CSE staff skilled in facilitation and conducting workshops of this sort would also be well placed to deliver the workshops.

[2] Formerly of Southampton University. Email: mjewell@gmail.com

1.4.3 Delivery of the technical and behavioural audit

Although it is possible that a skilled and confident facilities manager could use the ethnographic tools and the energy audit tool (a complex spreadsheet) in practice it is likely these tools will require support from CSE to enable their use. Skilled staff within the CSE research team will also be able to use them.

1.4.4 Design of communication materials

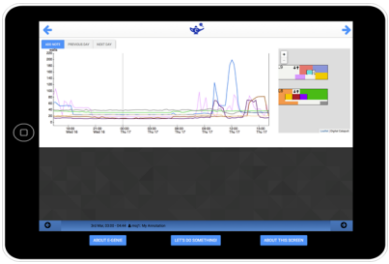
A competent facilities manager could use the guidance presented in this document to design materials for an energy awareness campaign. Again though, some assistance from CSE would be beneficial.

Each of these elements of the toolkit is described in further detail below.

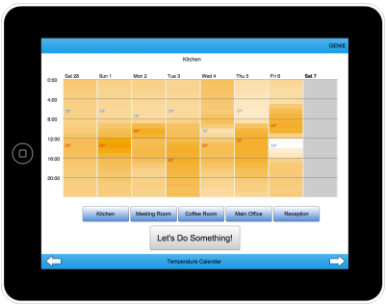
2 The e-Genie web application

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 tool's key functions are explained below:

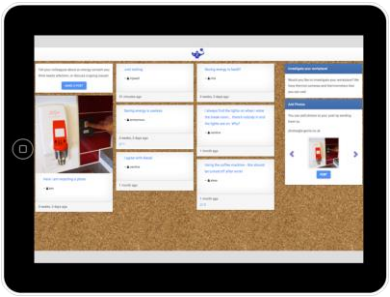
An **energy consumption dashboard**, providing data on workplace electricity use and heating. Live information can be annotated by staff, so that they can link particular activities with their energy footprint, while weekly views let staff track how their energy consumption has changed over the course of the week.



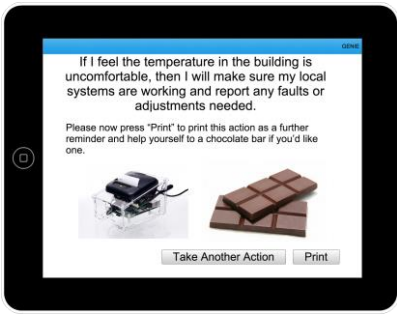
A temperature calendar, which shows half hourly temperature measurements over the previous week up to the present moment. This can be shown for multiple areas, allowing staff to understand how air temperatures relate to their comfort requirements in particular parts of the building.



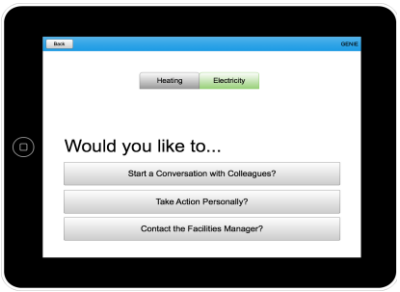
A **discussion space**, where staff are encouraged to identify energy-related issues in the workplace, and crowdsource potential solutions.



A **planning tool** through which staff can commit to a goal of reducing their energy footprint and are guided through a process of planning changes they could make.



A **communications channel** to the Facilities Manager (or equivalent role within the organisation) who holds responsibility for workplace energy management



These functions aim to:

- increase energy literacy by providing feedback on the temperature and electricity use in the space;
- provide an internal communication platform through the pin board and messaging features; encourage behavioural pledges to undertake specific energy related goals and to support pledge achievement through planning.

The e-Genie code is open sourced and instructions for setting up the system are shown below.

2.1 E-Genie deployment

2.1.1 E-Genie's components

- One or more tablet devices, used to display information to participants. These could be iPads or commodity Android tablets. They need to have network access and a web browser. In previous deployments we have mounted these on plinths.
- A *central server* which provides the user interface shown on the plinths, and stores data. This should be on the same network (possibly the internet) as the plinths.
- A number of *sensors*; these are simple battery-powered devices which sense temperature and humidity, or electrical power consumption. They each have an identity, and periodically broadcast their current reading using a simple radio protocol.
- One or more *radio receivers*, which act as a bridge between the sensors and central server. In the project's deployments these have been raspberry pi single board computers running the Raspberry pi operating system. They run a small bit of software which reads incoming radio transmissions and sends them on to the central server. These need to be on the same network as the central server.

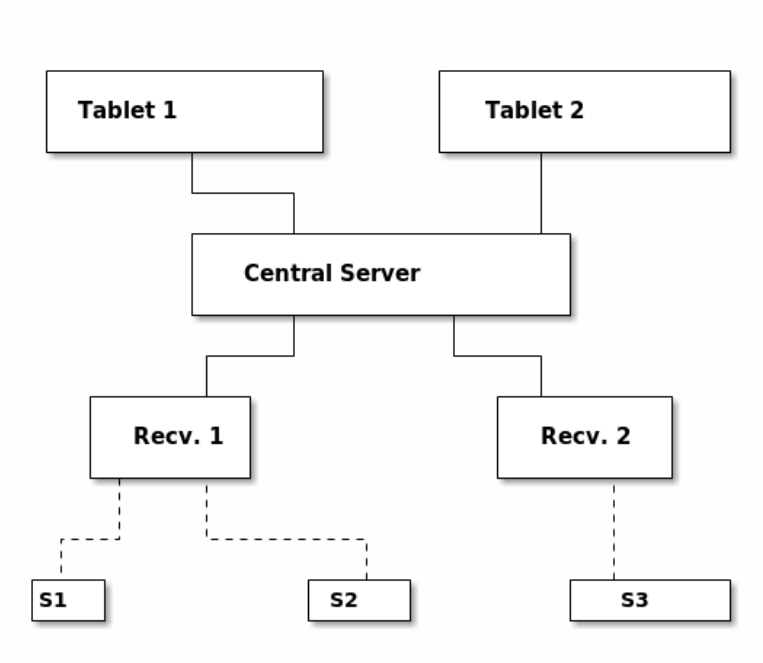


Figure 3 Indicative connections of components. S1, 2 and 3 are sensors, communicating with two receivers. These transmit data over the network to the central server, which presents it on the two tablets

2.1.2 Installing sensing equipment

If the scope of the deployment includes the temperature calendar, we must install temperature sensors in the workplace. These sensors are small, battery-powered thermometers that can be left on a shelf or stuck to a wall, and periodically send temperature readings back to a central hub. Multiple temperature sensors can be deployed in one building: this is recommended if temperature varies significantly between spaces. The central hub is a small, mains-powered computer (Raspberry Pi) that requires an internet connection to pass the temperature readings back to the e-Genie server. If appropriate, this connection can be via the workplace network; alternatively the hub can be connected to the internet via a mobile internet dongle.

2.1.3 Installing energy monitoring equipment

If the deployment includes the energy consumption dashboard, e-Genie requires access to electricity consumption data from the building. A non-invasive way to achieve this is to make data from an existing BMS accessible to e-Genie. Whether this is possible is dependent on the particular model and configuration of the BMS, and so will require assessment by the e-Genie team. If existing consumption data is not available, it may be possible for the e-Genie team to help install new energy monitoring equipment. This equipment must be physically clamped to electricity cabling within distribution boxes in the building, and so a certified electrician must carry out this process. Each new piece of electricity monitoring equipment must be physically connected to a central hub, which will typically sit within the distribution box. This hub requires mains power and access to the internet to pass electricity readings back to the e-Genie server.

2.1.4 Installing e-genie on organisation's IT system

e-Genie is a web application hosted on our own web servers. This means that it can be accessed by a standard web-browser from computers, tablets or smart phones, without installing any new software in the workplace. Depending upon the needs of a particular deployment, we are able to limit access to devices on a particular workplace network, or to a particular building or set of devices, preventing access outside the workplace. In every deployment we will need to work with the organisation's IT managers to ensure e-Genie collects data and is accessible in a way that meets all relevant IT policies and procedures.

2.2 Set up process

Installing E-Genie is not a simple 1-click process, and some technical skills are prerequisites. The installation process is detailed in the documentation for each part.

The first thing to install is the central server component, which is available from https://github.com/cse-bristol/312-e-Genie-deployment.

The top-level of this repository contains a README file describing how to install the program in detail. To follow the instructions you will need a Linux computer, and ideally some knowledge of:

- The nix package manager
- Python
- Django
- Mysql
- uwsgi
- nginx

After setting up your central server you will need to set up a radio receiver. Software to run on a receiver can be found at https://github.com/cse-bristol/312-ctech-hub.

This repository also contains a README describing how to install the program. You will need a raspberry pi with radio hardware and raspbian installed, and some sensors.

After setting up a receiver you will need to configure the receiver and the server to talk to each other. The process for this is documented in the README for the central server linked above.

2.3 E-genie licensing

e-genie is free software: you can redistribute it and/or modify it under the terms of the GNU Affero General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

3 Workshops

A key learning from the Ctech project was the value of conducting carefully structured workshops with staff. This allowed e-Genie data to be considered and for energy management solutions to be collectively developed. The workshops are designed to be run in sequence:

- Workshop 1. **Introduction and mapping**. Staff are introduced to the research project and the e-Genie toolkit. They are then asked to map activities in the workspace, comfort levels and the technologies used to achieve comfort within their building.

- Workshop 2 **Apportionment**. This workshop is about using data to work out what and who consumes energy. It also aims to identify who has control or influence over energy consuming practices.

- Workshop 3. **Causality and Strategy.** 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 (COM-B) behaviour change framework. COM-B is also used to work out the practical next steps for improved energy management in the workplace, recognising the need for staff involvement and engagement. The workshop also generates a list of behaviours that could be used to populate the e-Genie pledging tool.

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.

The detailed structure of each workshop is shown below in Appendix 1: Workshop structures. Powerpoint slides for each workshop are available as a separate file.

4 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.

There are 4 components to the audit tool:

1. Data collection sheet for use in a walk around survey
2. Interview topic guide for energy and facilities managers
3. "AEIOU" worksheet for recording information about use of the office environment using an ethnographic approach
4. Audit spreadsheet for data entry and calculations

Each of these is available as a separate file accompanying this document.

Standard energy auditing tools for workplaces typically compile technical information about the workplace and allow calculations of energy efficient alternatives. The data that is collected includes:

- An inventory of equipment,
- Current notional hours of daily usages and
- The associated specifications (power ratings etc).

Our core audit tool collects this information and performs the calculations necessary to estimate potential savings from installation of energy efficiency measures. However the associated tools allow collection of data on behavioural and social dimensions of energy use in the workspace.

It does this through providing sets of prompts which guide the auditor to uncover issues of control of equipment, ownership of space, guerrilla and forbidden energy using practices (such as the often-found under desk fan heater) and formal and informal hierarchies and group allegiances:

- The data collection sheet contains prompts to probe energy management practices,
- The topic guide for interviews with energy managers is also designed to record the social processes which influenced how equipment is actually used in practice and assesses the capabilities of the workforce to make changes (using the COM-B framework),
- The AEIOU worksheet provides a set of prompts for observing how equipment is used and how work practices (which may have an influence on energy consumption) are structured.

The evidence gathered using these tools feeds directly into the workshops outlined above.

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5 Guidance on designing energy engagement communications

C-tech research has revealed the complex and sometimes conflicting priorities of building users with respect to energy use. These different priorities are reflected in at least four framings of energy use:

1. as a utility,
2. as a cost,
3. as a right and
4. as a source of environmental pollution.

As a utility
Those in senior management responsible for setting the strategic direction of the organisation tend to think of energy as an invisible utility needed to be delivered at least cost but also safely and reliably so that the organisation can function.

As a cost
As an office based organisation's energy consumption will form an insignificant part of the cost of running the organisation (most of the cost will be in staff salaries). Energy use is also often not understood. Consequently it is difficult to put the cost into any context to see if it's too much, can be reduced etc. The net result is that energy demand reduction in office based organisations is not usually a priority. Of course, in some sectors, energy consumption can be a significant operating cost and so managing demand becomes more of a priority amongst senior management.

As a right
However, ordinary employees do not pay the energy bills and so tend to regard energy consumption as a right, essential as a means of maintaining comfort, appropriate working conditions and for occasionally powering equipment that may be needed during the course of the working day. A fourth framing of energy use is as a source of pollution and so the management of energy consumption, even in low energy intensity organisations, may become more of an issue if demand management serves a strategic function for example in demonstrating the organisation's green credentials to potential clients or shareholders.

As an environmental impact
Concerns about environmental aspects of energy use may be shared with members of staff right across the organisation.

5.1 Visualising energy consumption

The facilities manager steps into this rather complex mix of framings and agendas, seeking to deliver multiple objectives and to reconcile competing priorities wherever possible. In large and complex organisations this can be an extremely demanding task where existing management techniques result in solutions which are contested and suboptimal, where energy is wasted and where the potential contribution of employees is underused.

C-tech has identified a need for a decision support and communications tool that addresses this, facilitating multiple flows of information between and amongst building users and the FM (known as e-Genie).

This reconfigures the conventional logic of energy management away from a command and control model and moves towards a system encouraging greater co-management of the space. The tool allows ordinary employees to play a more active role in identifying energy wastage, reporting faults

with delivery of existing energy services, and to receive feedback on their own energy consumption. In turn the tool will allow the FM and members of staff to track resolution of issues, moderate discussion of the resolution process and inform building users of energy management decisions. We believe this approach will encourage better conflict resolution and a workforce that are as engaged as they need to be with the organisation's energy consumption - understanding why demand management is necessary and having the tools to play their part.

Ctech also resulted in some specific recommendations about the framing and delivery of communications drawing on the psychology of environmental and energy related behaviours in the workplace. This guidance to be used in the preparation of information campaigns including the design of posters and electronic messaging.

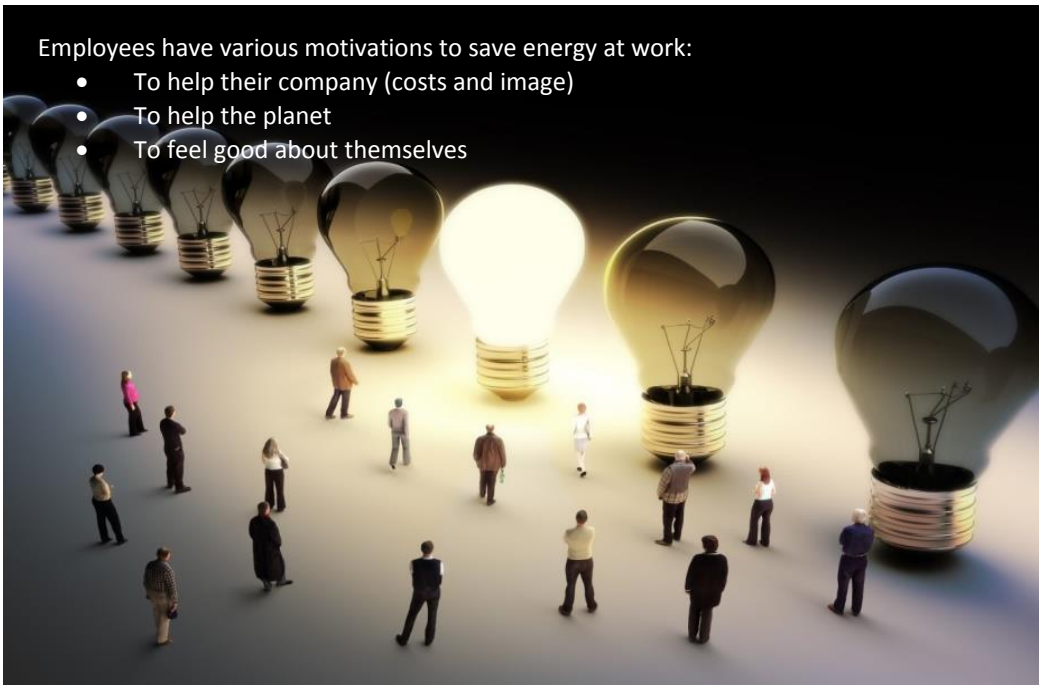
5.2 Framing messages

5.2.1 Appealing to peoples' motives and values orientations

People have enduring beliefs about the way the world works or should work. These deeply held beliefs are sometimes called "Values" or "Value systems". The research suggests our motives to act in particular ways are often rooted in a desire to behave in ways which are aligned with our values.

Therefore, messages about using energy efficiently in the workplace are more effective if they are framed to appeal to people's values. Ctech found 3 common motivations for saving energy in the workplace:

1. To help the company (an "altruistic" or "achievement" value set[3])
2. To help the planet (a "biospheric" value set)
3. To feel good about oneself (a "hedonistic" value set)



[3] An overview of the most commonly used framework for thinking about values, the Schwartz value set is found here: https://scholarworks.gvsu.edu/cgi/viewcontent.cgi?article=1116&context=orpc.

Of these motivations the environmental framing was found to be the most powerful: "Energy saving presented in terms of carbon dioxide, on the other hand, increased the extent to which people thought about climate change and this translated into greater intentions to undertake additional environmental behaviours (a behaviour spillover effect). It seems useful therefore to mention the environment when promoting energy saving to achieve broader impacts"[4].

Interestingly our research also found that where people were motivated to act because they felt it would enhance their self-image, then this kind of motivation negatively predicted energy saving behaviours. Evidently, behaving in an energy efficient way is not seen by some as a means of enhancing self-image. This leads to the finding that developing messages about how energy efficiency behaviours can enhance your reputation amongst colleagues should be avoided.

Focusing on reputation-building rewards can backlash!

So, to engage employees with energy saving, people can focus campaigns on altruism towards the organisation as well as environmental benefits. Reputation building incentives could be counterproductive, unless the organisation clearly values energy saving[5].

5.2.2 Loss or gain framing

We tested whether a loss frame or a gain frame was more effective. We found it made no difference.

[4] 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? J Env Psych. 38, 17-28

[5] Leygue, C., Ferguson, E., & Spence, A. Saving Energy in the Workplace: Why, and for Whom? Journal of Environmental Psychology Volume 53, November 2017, Pages 50-62

5.2.3 Being clear on cause and effect

Having clear and specific goals increases the chances of success. Also, associating a behaviour with a cue makes a big difference! So deciding when, where, and how you will save energy is key. For example, instead of saying "I will save electricity at work", make the pledge that "If you are the last one leaving the common room, THEN you will turn the lights off".

This kind of structure can be used to design pledge. A pledge making tool was a key feature of the e-Genie tool.

"IF you are the last one leaving the common room, THEN you will turn the lights off"

5.2.4 Create social and physical opportunities to save energy

Campaigns and interventions creating social and physical opportunities for employees to save energy are the most successful. These are the ones that enable employees to act through providing:

- Direct support to increase energy literacy and intellectual capacity and skills,
- A greater sense of control.

Physically and socially restructuring the workplace to give greater opportunity for efficiency is also key particularly using:

- Automated and retrofitted technologies and,
- Various forms of social influence (e.g., comparisons, social norms).

6 Ctech research digest

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

Apportioning energy consumption in the workplace

The majority of large buildings in the UK now provide automated energy meter readings: presenting this data back to building managers and users in a clear and actionable way can help to reduce energy consumption. However, the real value in this data can only be realised when it can be used to apportion consumption to the people, devices and systems that are responsible for the consumption, revealing why energy is consumed, and who might be able to change that consumption.

This review looks at apportionment from different perspectives: whether apportionment is technically feasible, how the social scale of apportionment might encourage or discourage behaviour change, and what tension might arise between apportionment, policy, organisational control and personal privacy.

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 in Technology Analysis & Strategic Management. Special Issue of Smart Metering Technology & Society. *1196-1211.*

Intervening to change behaviour and save energy in the workplace

This evidence review analyses research on energy related behaviour change in the workplace using the COM-B theoretical framework (COM-B stands for: Capability, Opportunity and Motivation - Behaviour change). This framework attempts to capture all relevant social, psychological and material dimensions thought to influence behaviour. Findings from the evidence review suggest that:

- Social and group norms and dynamics within an organisation are important in increasing employee motivations to act,
- Interventions can create new norms and standards regarding energy use in the office,

- Peer-education and modelling of particular employees holds potential and so personal contact and communications between colleagues with regards to possible energy saving actions can alter behaviours;
- Providing feedback on a group basis is more effective than when delivered individually;
- Whilst the information provided through feedback can be important, the manner in which such information is presented is equally significant and,
- Rewards and incentives given publically (rather than privately) are more likely to be effective, reflecting the importance of social influence.

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.

Understanding Energy Consumption at Work: Learning from Arrow Hill

Workplaces are complicated organisational and social environments and understanding who uses energy, where and why can be extremely difficult. Building management systems do very little to help building managers to unpack that complexity and develop informed behaviour change strategies. This paper looks back at early work with one on Ctech's non-academic partners, in which we brought stakeholders from all different perspectives together in one workshop to explore and critique data from their building management system. This data-driven conversation among the different participants demonstrated how operation of the building was understood in radically different ways across the organisation, that energy use was closely linked with everyday struggles to maintain staff comfort, and that - implicitly - policy was the primary interface between staff and energy consumption. Ultimately, this work revealed the potential for us to develop e-Genie in a way that engages staff in energy reduction through the perspectives of thermal comfort and policy negotiation

Bedwell, B., Constanza, E., Jewell, M. (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.

Caught in the middle: The role of the Facilities Manager in organisational energy use

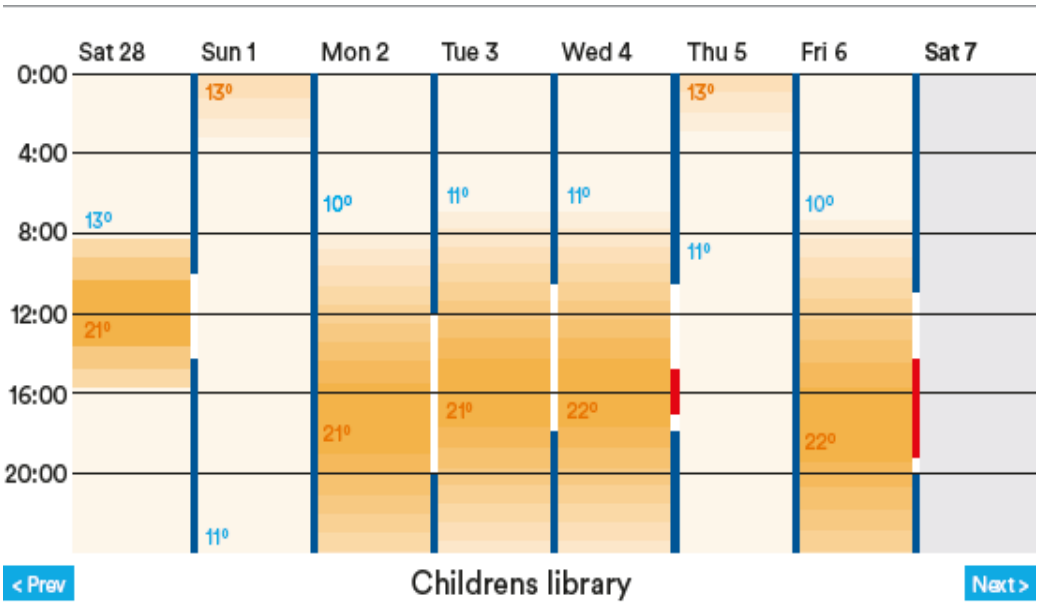
This study analyses the role of the Facilities Manager (FM) as a key actor in organisational energy management. This builds on the idea that ‘middle’ agents in networks can be an important lever for socio-technical change. The study demonstrates the considerable impact the FM can have on workplace energy consumption, whilst identifying a number of factors that constrain their agency and capacity to act. These include demands to meet workforce expectations of comfort; a lack of support from senior management; and a shortage of resources. Underlying these challenges, the study identifies three different energy rationales – that is to say conceptual frameworks – which are deployed by different groups of organisational actors.

The challenges of reconciling these at-times-contradictory rationales results in a picture of energy management which to the outsider can appear highly irrational. The paper concludes with a consideration of how policy makers can apply these insights to support energy reduction in workplaces.

Goulden, M. and Spence, A., (2015) Caught in the middle: The role of the Facilities Manager in organisational energy use. Energy Policy, Volume 85, Pages 280-287.

Libraries temperature calendar

The Temperature Calendar is a visualization of temperature variation within a workplace over the course of the past week. This highlights deviation from organizational temperature policy, and aims to bring staff "into the loop" of understanding and managing heating, and so reduce energy waste. The display was deployed for three weeks in five public libraries.



Analysis of interaction logs, questionnaires and interviews shows that staff used the displays to understand heating in their buildings, and took action to relate their libraries to organizational policy and improve thermal comfort. More in general, the study findings helped us to reflect on the role of policy on energy consumption, and the potential for the HCI community to engage with its application, as well as its definition or modification.

Constanza, E., Bedwell, B., Jewell, M., Colley, J., Rodden, T (2016) "A bit like British Weather, I suppose" Design and Evaluation of the Temperature Calendar in Proceedings ACM CHI.

Idlewars

IdleWars is pervasive game designed to raise awareness and promote behaviour change in relation to energy waste in the workplace. In the game, played using smartphones and computers, workers' pro-environmental or wasteful behaviour is reflected in their game score, and displayed through eco-feedback visualisations to try and call attention to energy wastage and potentially reduce it.

A field deployment, over two weeks in a medium sized organisation, revealed that the physical and competitive elements of the game work well in engaging participants and stimulating discussion around energy wasted and conservation. However, the game turned out to encourage also some anti-conservation behaviours, as participants appropriated the game and extended its rules, sometimes in a way that favoured engagement and fun rather than pro-environmental behaviour.

In general, our study uncovered how both the game and idle time reduction in itself can rub against the daily practices of the workplace.

Evangelos, T., Constanza, E., Rogers, A., Bedwell, B. Banks, N. (2015) IdleWars: an Evaluation of a Pervasive Game to Promote Sustainable Behaviour in the Workplace, In Proceedings International Conference on Entertainment Computing (ICEC)

Mention climate change to get broader environmental benefits

We explored different ways of engaging people with energy saving within experimental work. We

found that people naturally tend to think about cost information even when focused on environmental information but that information about cost savings of energy reduction were sometimes considered demotivating and '*not worth it*'. Energy saving presented in terms of carbon dioxide, on the other hand, increased the extent to which people thought about climate change and this translated into greater intentions to undertake additional environmental behaviours (a behaviour spillover effect). It seems useful therefore to mention the environment when promoting energy saving to achieve broader impacts.

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? J Env Psych. 38, 17-28.

Those concerned about energy costs are less accepting of smart energy technologies

This study focused on perceptions of demand-side management (DSM), which refers to a range of smart energy technologies and interventions designed to use energy more efficiently and flexibly. We found that, whilst energy costs are really important to people, those most concerned about energy costs were less likely to accept DSM.
We partly explain this with data that shows that those concerned about costs are also less willing to share energy data. People with less power in society may feel more vulnerable to exploitation and be more sceptical over payback from investments in smart energy technologies.

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.

Saving energy in the workplace: why, and for whom?

Determining motivations to save energy in the workplace is a necessary step in predicting how employees will respond to campaigns and incentives to reduce their energy use. Saving energy at work might be considered an altruistic behaviour, as often there are no personal benefits (people do not pay for their energy use at work). However we considered the possibility that energy saving could be motivated by self-oriented motivations as well. Our results show that there is a great potential for emphasising benefits to the organisation of energy saving in campaigns launched to reduce energy use. Indeed, we found in 3 studies that helping one's organisation (saving costs and getting a positive image) and environmental concern were rated as the most important motivations to save energy at work. Self-oriented motivations such as warm-glow (feeling good about oneself for doing the right thing) was also rated as an important motivation, but not reputation building in the workplace (unless when people perceive that the company values energy saving). So, to engage employees with energy saving, people can focus campaigns on altruism towards the organisation as well as environmental benefits. Reputation building incentives could be counterproductive, unless the organisation clearly values energy saving.

Leygue, C., Ferguson, E., & Spence, A. (in press). Saving Energy in the Workplace: Why, and for Whom? Journal of Environmental Psychology. Volume 53, November 2017, Pages 50-62

Energy feedback

Research has shown that energy displays can help consumers understand energy use and to reduce their energy usage. We looked at their effects in the workplace with two experiments 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 £), or both.

We found that the choice of units of energy feedback is important in the workplace as well as in the home. If the display includes numerical feedback, the small numbers in a £ cost display is likely to reduce instrumentality (participants' feelings that their savings can make a difference) which will in turn reduce energy saving intentions. However, these effects disappear when actual numbers are kept constant, and then we see that a cost feedback might be more impactful on energy savings, and a combined display could actually reduce saving intentions.

Engaging with energy reduction: Does a climate change frame have the potential for achieving broader sustainable behaviour? A.Spence, C.Leygue, B.Bedwell, C.O'Malley. Journal of Environmental Psychology 38 (2014) 17e28

Energy sharing at work

In the workplace, electricity is shared by employees, making it a public good that employees need to cooperate around. In this context, people can cooperate and reduce their energy use, or act selfishly and use more than their fair share (free-ride). We found that when a group is sharing their energy, if people cannot reprimand the ones who use too much, there is an escalation of energy use because people feel angry towards free riders and start using more themselves. These reactions 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 angrier towards people who use too much than if total energy use information is provided; they are also more likely to want them to receive a sanction (e.g., pay a fine), and are less likely to want to

reduce their energy use themselves. However, there are also cases where people cannot make any effort to contribute and reduce their energy use, and so could be considered as *legitimate* free riders. We found in our research that people react negatively (e.g., anger, fear) when there is a free rider in the workplace, even if electricity use is of no costs to them. Also, they prefer institutional responses (e.g., expect management to react) to personal sanctions. People react less negatively to legitimate free riders, and are even ready to reduce their own usage of electricity to compensate for this “fair overuse”. To conclude, campaigns around energy saving in the workplace should take into account social interactions and potential for negative reactions between employees.

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

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, 2, 29.

Appendix 1: Workshop structures

Ctech energy in shared spaces workshops

Introduction

Hi

Thanks for coming. [Introduce self and c-tech project. Explain role of participants].

Rationale for talking to building users:

60% of our energy consumption is in buildings so exploring ways of reducing energy consumption whilst maintaining comfort and functionality is an important thing to do. Buildings often don't perform as expected – sometimes they consume double what the designer thought they would. The reason for this is partly to do with how the buildings are used by staff. So in these workshops we are trying to understand how building services including heating lighting and use of equipment are actually used and also how to motivate building users to use their space more efficiently using information tools which we have specially designed with the sociology and psychology of the workspace in mind.

We are going to be doing three workshops:

1. The first workshop introduces the project and tells you about the IT tools we will deploy. This workshop also aims to produce a map of your comfort and the activities going on in different parts of the office.
2. The second workshop is about attributing energy consumption (both electricity for lighting and appliances and thermal energy to areas, activities and groups).
3. The third is about coming up with some strategies to reduce energy consumption whilst simultaneously allowing people to do their jobs in comfort.

Workshop rules
Set out rules of the workshop:

1. We will be recording
2. Gain consent
3. Try not to overtalk each other (as recording),
4. be honest – no wrong answers etc

Any questions?

Workshop 1: Introducing the toolkit and mapping the space

Workshop 1: Introducing the toolkit and mapping the space

Staff are introduced to the research project, the e-Genie toolkit and are then asked to map activities in the workspace, comfort and the technologies used to achieve comfort for their building.

Workshop requirements:

- Up to around 8 participants
- Projector
- Powerpoint presentation written for this workshop which includes a floorplan slide
- Very large piece of blank paper blu-tacked to wall (ideally A1 as a single piece, otherwise assemble 4 pieces of A3).
- Recommended that a large floorplan for a single representative floor is drawn onto one of the large pieces of paper above before the workshop starts (projecting the floorplan and tracing round the outline can help with this). Choose a floor that has most participants in the workshop primarily working on that floor. This to be blu-tacked to the wall.
- Flip chart with predrawn matrix showing 24 hour intervals on one axis and rows for various office activities. The matrix is to capture when activities occur through the day
- Thermal images captured with smart phone app preloaded into presentation
- Blu tack
- Thick and thin pens
- Large coloured dots (blue for winter comfort, yellow for summer comfort) – about 1 centimetre across

#	Aim	Exercise	Time (m)
1. Introduction	Introduce the workshop	State that the aims of the introductory workshop: • To introduce the projects aims and objectives • To introduce the features of e-Genie • To map ownership and control of energy use in the space • Describe content and timing of following workshops (W2 = apportionment of energy use - both thermal and power; W3 = causality and strategy for identified practices - could be either thermal or power related. Populate pledge tool). Any questions?	5
Introducing e-Genie	To introduce the e-Genie tool	Describe the purpose of the tool and how it fits with the workshops. Describe each of the functions (see appendix for screen shots and descriptions):	10

<table>
<tr>
<td></td>
<td></td>
<td>

annotation tool
temperature calendar
pin board
pledge
comms channel

Ask if people have any questions about:

the data provided
the data presentation formats
where the data will be viewable
use of the pin board/pledging/comms channel

</td>
<td></td>
</tr>
<tr>
<td>Activities in the space</td>
<td>To generate a sense of the activities in the space and equipment used to achieve these activities</td>
<td>
Print floorplan of the space on A3 or larger paper or project floorplan onto very large piece of blank paper blu-tacked to wall (ideally A1 as a single piece, otherwise assemble 4 pieces of A3). Trace onto the paper the projection of the floorplan. Advisable to do this before the workshop

Note - there is no time to do this for every floor of every building in a large organisation. Need to do it for a single floor of a single building which as broad a diversity of activity on it as possible - e.g. a mix of office space, meeting rooms, clinical areas, lecture theatres etc

Activities in the space (5 mins on this)
Ask:

What activities are in the various spaces?

Write answers onto the map.

How does the activity or usage for a particular space change through the day

Could tabulate this on a flip chart:
<table>
<tr><td></td><td>midn ight</td><td>1:00 AM</td><td>2:00 AM</td><td>etc</td></tr>
<tr><td>Activity 1: working at desks</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Activity 2: making tea</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Activity 3: eating lunch</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Activity 4: running server back up</td><td></td><td></td><td></td><td></td></tr>
</table>
Equipment for activities (5 mins)
Ask:

“What equipment and services are needed to deliver the services e.g. computers, lighting, printing presses, copiers?

</td>
<td>10</td>
</tr>
</table>

		Summarise activities and associated equipment and identify any "hotspots" areas or activities where it appears that there is particularly intensive power consumption	
4. Comfort in the space	To generate an activity and comfort map of the workplace	**Comfort where you sit and in shared space (5 mins)** Ask each participant to indicate comfort for where they work (e.g. their desk) using smiley, neutral, sad faces on the dots provided: • Blue dots for winter comfort. • Yellow dots for summer. For shared spaces such as meeting rooms facilitator should attempt to gather consensus vote and stick up stickers appropriately. **Technology and behaviours for comfort (5 mins)** Ask: • what technology is used to provide thermal comfort (air conditioning /radiators etc) in each part of the office • What are the behaviours used to be comfortable? (clothing, where you sit) • write answers into the map (location of radiators, warm air grilles, behaviours of occupants) Facilitator summarises dot distribution and asks for clarifications – e.g. "is it because it is too cold/warm/drafty here?"	10
5. Mapping air temperature	To overlay the comfort map with "objective" measures of air temp from temp calendar tool	Indicate position of temperature sensors. Project e-Genie temperature calendar onto whiteboard. Compare comfort levels revealed by dots with the temperature calendar temperatures. Write actual temperatures onto the comfort map for 9:00, 12:00 and 4pm for a weekday. Ask: • What this reveals about comfortable air temperatures.	5
6. Mapping thermal images	To map the thermal imaging results	Present thermal images for the office (these will obviously need to be captured before the workshop). Thermal images should be projected as part of the presentation used to guide the workshop	5

		Draw onto the map areas of low and warm surface temperature with blue and red pens. Ask: • How revealed surface temperatures relate to comfort	
7. Wrap up	To bring together workshop findings	Summarise main learnings from the workshop, give any homework and say how the findings from this workshop will be used in the next workshop: • key comfort issues • key power issues • e-Genie is coming – please use it when it becomes available • we will be distributing a questionnaire amongst all staff following this workshop – please encourage your colleagues to complete it	5
Total time			50
Write up of workshop	To create a record of the groups thinking of comfort issues	Post workshop the facilities manager or nominated energy champion should scan annotated floor plans and write up the workshop findings. This document is then used as a reference for the subsequent strategy workshops.	1 -2 hours

Workshop 2: Who or What consumes energy and how it is controlled

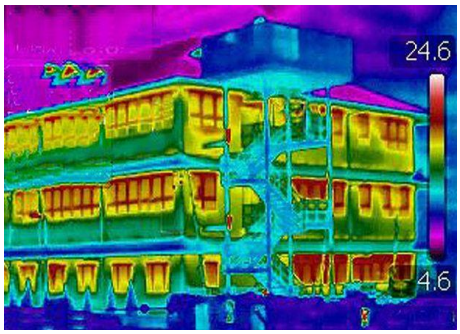
Workshop 2: Apportionment

This workshop is about working out what and who consumes what using energy data. It also aims to identify who has control or influence over energy consuming practices.

Workshop requirements:

- Up to around 8 participants
- Projector
- Powerpoint presentation written for this workshop
- Map of workspace generated in workshops 1 and 2 – either as a photograph that can be projected or the hard copy that is then stuck up on a wall
- If no electricity annotation tool is deployed need 2 X very large pieces of paper (ideally A1) to project time-stepped energy consumption data onto - 1 piece for a weekday, 1 piece for the weekend. The projection is then traced onto and annotated.
- Possibly also produce A3 print offs of time stepped energy consumption
- Blu tack
- Thick and thin pens

#	Aim	Exercise	Time
Introduction	Introduce the power and thermal energy apportionment workshop	State that the aims of the apportionment workshop are: • To think through how energy is used in the office • To allocate ownership and control of the power consuming activity Any questions?	2
Using power and heat /coolth in the space	To recap the mapping work in workshop 1	Project photograph of mapped floorplan generated in previous workshop. Or stick up hard copy map and run through it.	3
Partitioning space by staff grouping	To explore whether distinct groups of staff occupy particular areas and whether groups and individuals have a sense of ownership over their area - i.e. the degree to which they are invested in their area.	Ask: • Are different areas occupied by distinct groups of staff? (if not already determined) • Do individuals care about the area they occupy? • If distinct groups occupy distinct areas ask how the group feels about the area they occupy Note : groupings will generally be determined by job description or department. In some organisations a department will sit together. In	5

		others departmental staff may be scattered.	
Thermal energy consumption	To use thermal images to explore which parts of the office have highest/lowest surface temperatures	Project thermal images captured by smart phone app below:  (Draw areas of high / low surface temperature onto the office map) Ask • What does this tell us about comfortable air and surface temperatures? (e.g. is there a match between low surface temperatures and areas of low comfort) • Which areas of the office appear to be consuming most thermal energy (because they have low surface temperatures and therefore create greater heat transfer)?	10
Electrical energy consumption	To apportion electricity use to area / activity	Use annotation tool in a group setting. Project e-Genie electricity trace so that all can see and comment. One person gathers the views of the room and writes the annotation. If annotation tool not deployed use whatever electricity consumption data is available. A graph can be projected onto a piece of paper and the annotated directly. A3 print outs of time stepped electricity data can also be distributed as a reference and a means of examining the graph more closely Explore 24 hour period using half hourly data for weekdays and weekends. This data to be as disaggregated as metering allows – e.g. ring main, server room, lighting. • Identify probable causes of any peaks and troughs • Disaggregate demand curve as much as	15

<table>
<tr>
<td></td>
<td></td>
<td>possible - but don’t spend too long on this as could be an exercise that takes as long as people want it to with lots of speculation

For 1 or 2 activities identified as creating significant electrical demand identify:

• who or what causes the demand
• Estimate peak power demand of particular activities
• the extent to which the demand can be attributed to a group activity

Write responses as annotations direct straight into the electronic tool. Or use a table written onto a flip chart

<table>
<tr><th>Weekday</th><th>Estimate of peak power demand (kW)</th><th>Group activity? (attributable to all staff or a distinct group of staff)</th></tr>
<tr><td>Activity 1</td><td></td><td></td></tr>
<tr><td>Activity 2</td><td></td><td></td></tr>
<tr><td>Activity 3</td><td></td><td></td></tr>
</table>

<table>
<tr><th>Weekend</th><th>Estimate of peak power demand (kW)</th><th>Group activity? (attributable to all staff or a distinct group of staff)</th></tr>
<tr><td>Activity 1</td><td></td><td></td></tr>
<tr><td>Activity 2</td><td></td><td></td></tr>
<tr><td>Activity 3</td><td></td><td></td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>Control of equipment and thermal energy</td>
<td>To understand who has the ability to control energy used for thermal energy electrical power in the space</td>
<td>Power
• Who has control, or can influence the power consuming activities in each space?
• Who should have control?

Thermal
• Who has control, or can influence the thermal energy consumed activities in each space?
• Who should have control?

Write results into a table on a flip chart or</td>
<td>15</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td>directly onto the map if hard copy map is used.

<table><tr><th>Services</th><th>Existing control?</th><th>Who should have control?</th></tr><tr><td>Service 1 (e.g. heating in main office space)</td><td></td><td></td></tr><tr><td>Service 2 (e.g. air conditioning in main office space)</td><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>Wrap up</td><td>To bring together workshop findings</td><td>Summarise main learnings from the workshop and say how the findings from this workshop will be used in the next workshop.

• Groupings?
• Groupings associated with areas?
• Disaggregation of power - main activities using power
• Control of services using electrical energy?
• Control of services using thermal energy?</td><td>5</td></tr>
<tr><td>Total time</td><td></td><td></td><td>55</td></tr>
<tr><td>Write up of workshop</td><td>To create a record of the groups thinking of what consumes what</td><td>Post workshop the facilities manager or nominated energy champion should scan annotated floor plans and electricity trace and generally write up the workshop findings. This document is then used as a reference for the subsequent workshop.</td><td>1-2 hours</td></tr>
</table>

Workshop 3: Strategy for better energy management

Workshop 3: Strategy (power and comfort)
The current success of heating, cooling and ventilation practices will be assessed and improvements suggested using the behaviour change wheel as a framework. The workshop also generates a list of behaviours that could be used to populate the e-Genie pledging tool.

Workshop requirements:

- Up to around 8 participants
- Projector
- Powerpoint presentation written for this workshop
- Map of workspace generated in workshops 1 and 2 – either as a photograph that can be projected or the hard copy that is then stuck up on a wall
- Flip chart or very large pieces of paper with the following matrices already drawn up and headed :
  1. Alternative comfort practices table
  2. Alternative power practices table
  3. Prioritisation 2 X 2 for power
  4. Prioritisation 2 X2 for comfort
  5. Capability, Opportunity, Motivation table (see appendix)
- Blu tack
- Thick and thin pens

#	Aim	Exercise	mins
Introduction	To recap the findings from the mapping and apportionment exercises and describe workshop aims	Facilitator projects or sticks up the map and recaps main findings. Use tables for thermal and power related services developed in previous workshop: Power services: Services | Existing control? | Who should have control? Service 1 (e.g. lighting in main office area) Service 2 (e.g. electricity used by desk top computers) Thermal services: Services | Existing control? | Who should have control? Service 1 (e.g. heating in main office space) Service 2 (e.g. air conditioning in main office space)	5

<table>
<tr><td></td><td></td><td>Explain that this workshop is about developing some ideas for how we make existing work practices more energy efficient.</td><td></td></tr>
<tr><td>An efficient alternative?</td><td>To ask attendees to think about whether there are more energy efficient methods for achieving comfort or work tasks requiring power</td><td>

Thermal services / Comfort
Write up 2-3 thermal services or comfort practices (e.g. heating space X to Y degrees using equipment Z) from tables developed in workshop 2 and ask:

- if more efficient alternative practices could be found

<table>
<tr><th>Existing activity or service</th><th>Existing control ?</th><th>Efficient alternative?</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Note: these efficient alternatives will be used to populate the pledging tool.

Power
Write up 2-3 work practices requiring power (e.g. lighting meeting rooms/main space, running servers and heating food) using tables developed in workshop 2 and ask:

- if more efficient configurations or versions of the practice could be found

As for comfort, write these up into a table:

<table>
<tr><th>Existing activity or service</th><th>Personal or group control?</th><th>Efficient alternative?</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Note: these efficient alternatives will be used to

</td><td>15</td></tr>
</table>

<table>
<tr><td></td><td></td><td>populate the pledging tool.</td><td></td></tr>
<tr><td>Prioritising efficient alternatives</td><td>To select one efficient practice for further analysis by positioning results from exercise 2 on a 2 X2</td><td>Introduce the Influencability-savings 2X2.
Explain what is meant by “Influencability”.

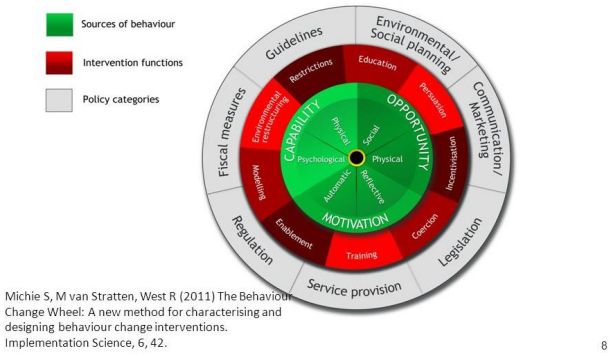
Influencability = the degree to which ordinary members of staff can make a change to their behaviour or work practice towards a more efficient way of doing things if given the right support

Note : Here we are primarily interested in behaviours which can be changed by the individual or group rather than changes to system set up that are under the control of the facilities manager (i.e. under 3rd party influence).

Note also that even changes to settings under sole control of the facilities manager will need acceptance of staff if they are to achieve desired effects. Without acceptance unintended behaviours can result which result in even greater energy consumption – e.g. clandestine use of under desk fan heaters.

Write the grid on a flipchart. Ask participants to position the power and comfort behaviours identified above on the grid.

Example efficient comfort related behaviours:
<table><tr><td rowspan="2">Influencability</td><td>High</td><td>Getting people to shut doors on leaving meeting rooms to allow TRVs to work</td><td>Stopping split ac units fighting heating by increasing deadzone</td></tr><tr><td>Low</td><td>Getting people to change the way they dress</td><td>Keep windows shut in heated/cooled space</td></tr><tr><td></td><td></td><td>Low</td><td>High</td></tr><tr><td></td><td></td><td colspan="2">Possible savings</td></tr></table></td><td>10</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>Example efficient power related behaviours:
<table>
<tr><td rowspan="2">Influencability</td><td>High</td><td>Banning electric heaters in winter (under desk fan heaters)</td><td>Switching off lighting in unnecessarily lit spaces (e.g. car parking during the day)</td></tr>
<tr><td>Low</td><td>Not leaving computers / monitors on overnight</td><td>Changing version control habits so that server room does not operate so energy intensively</td></tr>
<tr><td></td><td></td><td>Low</td><td>High</td></tr>
<tr><td></td><td></td><td colspan="2">Possible savings</td></tr>
</table>
Ask participants to select which behaviour they want to work with further. Ideally the behaviour should be in green or orange quadrants.</td>
<td></td>
</tr>
<tr>
<td>Introducing the behaviour change wheel</td>
<td>To explain the basic structure of the BCW</td>
<td>Introduce behaviour change wheel. Explain that we are going to use this tool to work out what will be needed to change the practice. Explain the meaning of each behaviour change wheel category


Michie S, M van Stratten, West R (2011) The Behaviour Change Wheel: A new method for characterising and designing behaviour change interventions. Implementation Science, 6, 42.
Ask people to call out example of specific categories to ensure they understand the general theory.</td>
<td>5</td>
</tr>
<tr>
<td>Working through the COM-B framework</td>
<td>To get participants to explore why existing practices occur and what needs to change to improve comfort or operate equipment more efficiently</td>
<td>For 1 or, ideally, 2 (if time permits) efficient alternative identified as a priority using the grid above ask participants to work through BCW categories. Aim to work through 1 comfort practice and 1 power practice.

Before starting recap the meaning of each category in the COM matrix.

Draw the grids onto a big piece of paper and write straight onto it. (see appendix)

Note: these grids should be prepared beforehand to</td>
<td>10</td>
</tr>
</table>

<table>
<tr><td></td><td>using the COM-B framework.</td><td>save time.

<table>
<tr><td></td><td colspan="2">Capability</td><td colspan="2">Opportunity</td><td colspan="2">Motivation</td></tr>
<tr><td></td><td>Psychological</td><td>Physical</td><td>Social</td><td>Physical</td><td>Automatic</td><td>Reflective</td></tr>
<tr><td></td><td>Knowledge or psychological skills, strength or stamina to engage in the necessary mental processes</td><td>Physical skill, strength or stamina</td><td>Opportunity afforded by interpersonal influences, social cues and cultural norms</td><td>Opportunity afforded by the environment involving time, resources, locations, cues, physical 'affordance'.</td><td>Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex response.</td><td>Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad. Commitments.</td></tr>
<tr><td>Behaviour 1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Behaviour 2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>etc</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
Optional additional exercise:
Return to “prioritising 2X2” to see if participants sense of Influencability has shifted following BCW exercise.</td><td></td></tr>
<tr><td>Intervention</td><td>To identify how a number of suggested interventions can influence the needs under each COM-B heading</td><td>If there is time now ask the group to think of one or two interventions aiming to achieve each efficient alternative identified above (thermal and power) e.g. an awareness campaign or handover of control of a lighting controller or thermostat to a nominated member of staff or a group level competition.

For each efficient alternative go through the COM-B categories considering if the intervention creates the needed factors identified under each category.

For example if the group identifies the need for a awareness campaign to drive more energy efficient lighting practices in the main office space ask if an awareness campaign would give people the needed:

• psychological skills
• physical skills
• social opportunities
• physical opportunities
• automatic motivations
• reflective processes leading to conscious motivations

If time permits do this more than one intervention to compare which intervention ticks more com-b boxes and is therefore more likely to success.

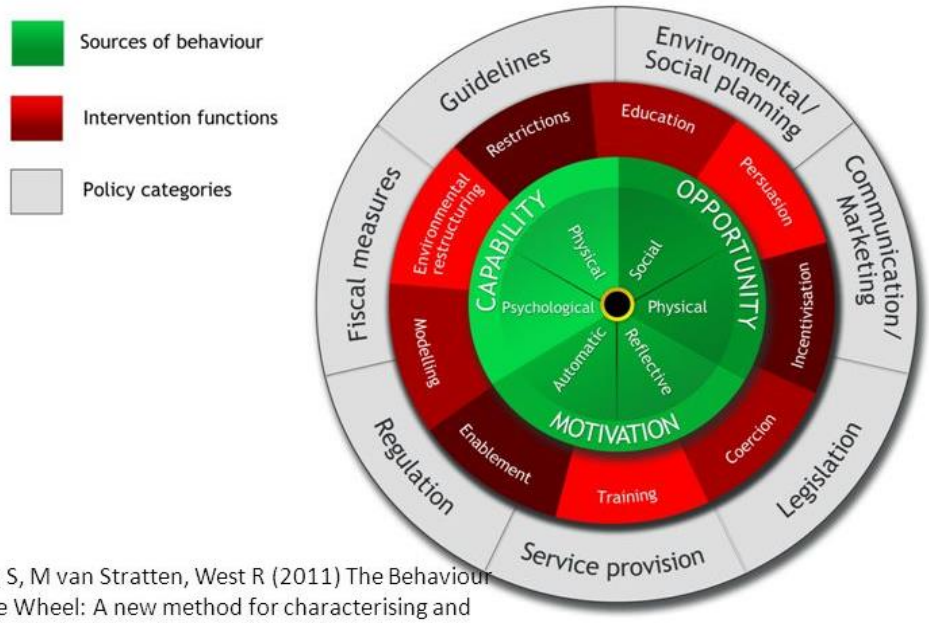
If time permits do this for both a power efficient alternative and a thermal efficient alternative.</td><td>10</td></tr>
<tr><td>Wrap up</td><td>To summarise workshop findings</td><td>Summarise the main workshop findings. Indicate what will happen next with workshop findings:

• Priority thermal practices to work with</td><td>5</td></tr>
</table>

		• Priority power using practices to work with • e-Genie switch on • questionnaire number 2	
Total time			60
Write up of workshop	To create a record of the groups thinking on comfort issues	Post workshop the facilities manager or nominated energy champion should write up the workshop findings, particularly actions / pledges considered.	1 -2 hours

Behaviour Change Wheel

Diagram of the behaviour change wheel to be shown during the workshop to explain its underlying logic[6]



Michie S, M van Stratten, West R (2011) The Behaviour Change Wheel: A new method for characterising and designing behaviour change interventions. Implementation Science, 6, 42.

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[6]Further detail of the theory and application of the behaviour change wheel is found at: http://www.behaviourchangewheel.com/

COM-B terms

This table explains the various COM-B terms in greater detail.

Capability		Opportunity		Motivation	
Psychological	Physical	Social	Physical	Automatic	Reflective
Knowledge or psychological skills, strength or stamina to engage in the necessary mental processes. Capacity to engage in the necessary thought processes– comprehension, reasoning.	Physical skill, strength or stamina	Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way that we think about things (e.g. words and concepts that make up our language)	Opportunity afforded by the environment involving time, resources, locations, cues, physical 'affordance'. Enabling physical opportunity—existence of physical opportunity afforded by the environment. Restrictive physical opportunity—lack of physical opportunity afforded by the environment	Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex response. Emotions and impulses that arise from associative learning and/or innate dispositions	Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad. Commitments. Engagement (defined as a state of mental willingness)

Examples of Influencability tables

These are to be used in the workshops to help staff prioritise which measures they should focus on as part of an energy management strategy.

Example 1

Influencability	High	Banning electric heaters in winter (under desk fan heaters)	Switching off lighting in unnecessarily lit spaces (e.g. car parking during the day)
	Low	Not leaving computers / monitors on overnight	Changing version control habits so that server room does not operate so energy intensively
		Low	High
		Possible savings	

Example 2

Influencability	High	Getting people to shut doors on leaving meeting rooms to allow TRVs to work	Stopping split ac units fighting heating by increasing deadzone
	Low	Getting people to change the way they dress	Keep windows shut in heated/cooled space
		Low	High
		Possible savings	

Plotting activities over time

This table can be used to help workshop participants identify when energy consuming activities are taking place.

	midnight	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Activity 1: working at desks																								
Activity 2: making tea																								
Activity 3: eating lunch																								
Activity 4: running server back up																								

Power practice table

As part of the third workshop staff should have an opportunity to select a particular measure that they feel hold promise for being both influencable and that will achieve energy savings. The com –b framework should then be applied to identify which capabilities, opportunities and motivations are required to sustain the efficient measure. Various interventions (e.g. an awareness campaign) can then be analysed to assess the extent to which they bring about the capabilities, opportunities and motivations. The table below shows how this information can be captured in a workshop setting. The Com-b tables should be copied onto flip chart or A1 paper before the workshop and then stuck up and written into.

	Power behaviour - e.g. lighting only used as necessary in main office area					
	Capability		Opportunity		Motivation	
	Psychological	Physical	Social	Physical	Automatic	Reflective
	Knowledge or psychological skills, strength or stamina to engage in the necessary mental processes	Physical skill, strength or stamina	Opportunity afforded by interpersonal influences, social cues and cultural norms	Opportunity afforded by the environment involving time, resources, locations, cues, physical 'affordance'.	Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex response.	Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad. Commitments.
Aspects of each COM-B category needed for efficient alternative to happen						
Intervention 1: awareness campaign	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?
Intervention 2: task lighting	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?

Thermal practices table

The thermal practices table should be used in the same way as the power behaviour table described above.

	Efficient thermal behaviour 1					
	Capability		Opportunity		Motivation	
	Psychological	Physical	Social	Physical	Automatic	Reflective
	Knowledge or psychological skills, strength or stamina to engage in the necessary mental processes	Physical skill, strength or stamina	Opportunity afforded by interpersonal influences, social cues and cultural norms	Opportunity afforded by the environment involving time, resources, locations, cues, physical 'affordance'.	Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex response.	Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad. Commitments.
Aspects of each COM-B category needed for efficient alternative to happen						
Intervention 1 E.g. awareness campaign	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?
Intervention 2: E.g. Give control of thermostat to energy champion	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?	yes/no/maybe?

Appendix 2: Example of the offer document

energyforchange.ac.uk

e-genie.co.uk

Proposal to [your organisation] for deployment of the C-tech toolkit
This note is a proposal to [your organisation] for testing a toolkit being developed out of a 5 year research project aiming to find ways of encouraging energy efficient behaviours in the workplace. The project is funded by the Economic and Physical Sciences Research Council (EPSRC) and is a collaboration of the Universities of Nottingham and Southampton and the Centre for Sustainable Energy, a national energy charity based in Bristol.

The toolkits' centrepiece is a web hosted application called e-Genie which is designed to facilitate communication about energy issues between staff and facilities management and to provide some tools to help behaviour change. We think it will be particularly useful as a tool for energy/environmental champions to work with in large complexly serviced environments like a hospital. Below we give further detail of the project and how we would like to work with [your organisation] as a possible site for deployment.

Overview of our activities
For the past four years, the C-tech project has investigated innovative ways of dividing up and representing energy use in shared workplace buildings to motivate occupants to save energy. Based on the results of our research in energy monitoring, psychology and sociology, we have built a toolkit to facilitate behaviour change which we believe will be of particular value to anyone managing energy consumption in an organisation. The centrepiece is e-Genie: a web based application with functionality aimed engaging staff, increasing energy literacy, guiding behaviour change and creating a space to facilitate communication between staff and facilities management.

Recognising that technology alone is no solution to complex organisational challenges, the toolkit includes workshops and supporting materials to help integrate e-Genie within existing working practices and roles, and develop new supporting roles amongst staff. Both the C-tech toolkit and e-Genie itself are designed to be modular to flexibly accommodate the different needs of different organisations.

In order to aid both the deployment of the toolkit within your organisation, and C-tech's research learning, an ethnographer from the team will spend time on site prior to, and during, deployment. Their task is to understand how workplace practices result in patterns of energy consumption, tailor the toolkit to existing energy challenges in your workplace, monitor its performance and collect feedback. These findings will contribute to the generation of a report for your organisation at the end of the deployment.

Engagement and Behaviour Change at [your organisation]
Description of the energy management needs of the organisation

e-genie needs to work in harmony with existing systems . Therefore in the context of working with existing systems it was felt that the c-tech toolkit could offer some useful functionality:

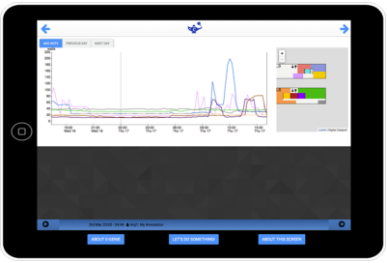
- Improving communications between staff and FM via the notice board and all parties being able to refer to credible sources of information such as the temperature calendar. Also by providing a space to have crowd sourced conversations about energy management of the space – listening to this conversation means that solutions will have greater resonance and relevance.
- Improving energy literacy, for example by being able to explore how the temperature in a space varies through the day and week to week. The always on tool was also thought to offer a useful entry point for engagement on baseline consumption (to be explored further in a workshop context)
- In tandem with the workshops, using e-genie information to work up solutions that have staff buy-in
- Providing a further impetus for staff to undertake small measures in the workplace through e.g. the pledging tool.

The facilities team also identified a couple of specific buildings where the tool could be of particular benefit. :

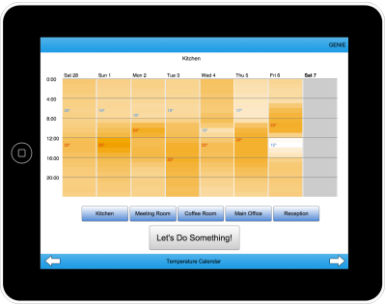
e-Genie: Energy Goal-setting and Information Engagement

e-Genie is a web application accessed via interactive touchscreens installed at appropriate locations within the workplace or via standard desktop computer. It includes five components:

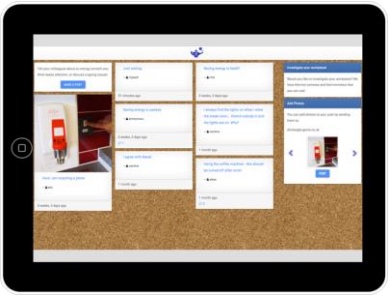
An **energy consumption dashboard**, providing data on workplace electricity use and heating. Live information can be annotated by staff, so that they can link particular activities with their energy footprint, while weekly views let staff track how their energy consumption has changed over the course of the week



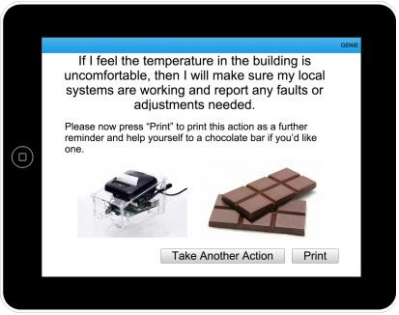
A temperature calendar, which shows half hourly temperature measurements over the previous week up to the present moment. This can be shown for multiple areas, allowing staff to understand how air temperatures relate to their comfort requirements in particular parts of the building.



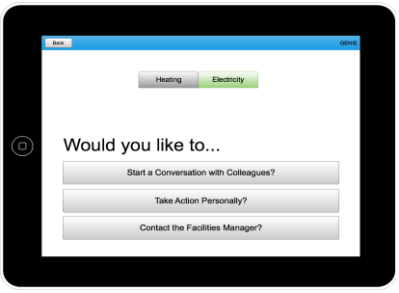
A **discussion space**, where staff are encouraged to identify energy-related issues in the workplace, and crowdsource potential solutions.



A **planning tool** through which staff can commit to a goal of reducing their energy footprint and are guided through a process of planning changes they could make.



A **communications channel** to the Facilities Manager (or equivalent role within the organisation) who holds responsibility for workplace energy management



Workshops and supporting material

e-Genie works best when the information and interest it generates is harnessed and worked with further. For this reason the team has created a number of workshops and written materials which both support use of e-genie and draw on its outputs to build grounded energy management strategies which have the buy in of both facilities managers and staff. We have developed 3 workshops:

> Workshop 1. **Introduction and mapping**. Staff are introduced to the research project and the e-Genie toolkit. They are then asked to map activities in the workspace, comfort levels and the technologies used to achieve comfort within their building.
>
> Workshop 2 **Apportionment**. This workshop is about using data to work out what and who consumes energy. It also aims to identify who has control or influence over energy consuming practices.
>
> Workshop 3. **Causality and Strategy (power and comfort)** 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 (COM-B) behaviour change framework. COM-B is also used to work out the practical next steps for improved energy management in the workplace, recognising the need for staff involvement and engagement. The workshop also generates a list of behaviours that could be used to populate the e-Genie pledging tool.

Each workshop is designed to run for an hour (i.e. over a lunch hour) with a target audience of 8-10 facilities staff, energy managers, energy champions and general staff. Results of workshops are captured using purposely designed methods which can then be disseminated more widely, commented upon and then used to build an evidenced energy management strategy which has full buy in from all staff.

Outputs for the organisation

e-Genie is a result of the latest research in energy monitoring, psychology, and sociology. Organisations participating in the c-tech project will benefit in a number of ways:

- Report of the results including participant satisfaction; projected energy savings; and concerns and future intentions of your staff regarding energy saving.
- Assistance in moving towards an energy-saving culture in your workplace
- Provision of a new communications channel for staff engagement
- Improved transparency of your existing energy infrastructure.

Certain aspects of e-Genie can also be provided publicly online to highlight and demonstrate the activity going on in the organisation.

There is no cost for involvement with the C-tech project other than the cost of staff time from your side. Prior experience with deployment suggests that this need not be significant but organisations are of course welcomed to put in as much resource to this as they wish.

Deployment process

C-tech can be entirely flexible in what is deployed over what period. e-Genie is designed to be modular so that, for example, if [your organisation]do not wish to deploy a particular function of e-

genie or to run a workshop then that is entirely at UHB's discretion. A standard deployment usually has the following sequence:

- Around two weeks before deployment, we propose 2 team members will come on-site for one or two days to **understand** your workplace's infrastructure and practices. It would be useful for them to meet with your Facilities Manager to ensure we tailor the intervention in a way which is useful to them, and observe the workplace to understand how energy is currently managed and used. They will seek to conduct short interviews with willing staff about current energy use.

- Shortly before deployment, with your consent we'll also send a **questionnaire** to your staff via email to understand current workplace energy use. We are also keen to identify one or two staff who are interested in acting as *Energy Champions*, either in consultation with the FM (or other appropriate management), or by email request alongside the questionnaire. *Energy Champions* will liaise between the workplace and the Ctech team during the deployment.

- On the day of deployment we will install e-Genie and will aim to engage as many of your staff as possible by running a **seminar** to communicate the project to staff during a staff meeting, and by distributing **promotional material** to raise awareness of Ctech and e-Genie. We will also have a couple of thermal imaging camera add-ons for smart phones that will be able to be lent out to staff so that they can explore the building, assisting in understanding and contributing to the energy consumption dashboard - we suggest that following deployment these are left with an appropriate person from which staff can borrow and return these.

- Once e-Genie is deployed staff will be able to interact with the installed touch screens to explore our visualisations of your workplace's energy consumption, create energy-saving goals and discuss ways to reduce energy use. During this time, our ethnographer will spend time observing interactions with and around e-Genie, and take appropriate opportunities to discuss the impact of the system with staff.

- We will also work with facilities managers to organise one or more workshops with staff (see above) which draw on e-genie information and aim to arrive at new energy management strategies which are grounded in the realities of staff behaviours and facilities managers' needs.

- Later in the deployment, (approximately two weeks after initial deployment) we will email a short follow-up questionnaire to already participating staff to evaluate the impact of e-Genie on their energy-related attitudes and behaviour.

We are sensitive that this is a working environment where people are busy, and are keen to work with you to fit in, by using existing communication channels and to be flexible around current activities.

Timescales

In terms of timings we can be very flexible about this to fit in with [your organisation] requirements. Ideally we would expect to have the system in place for at least 6 weeks. This is sufficient time to give staff an opportunity to familiarise themselves with the functionality and to make behavioural changes. Also for the system to be used and experimented with enough times such that if and when

the system is withdrawn learnings and behavioural changes have a good chance of remaining embedded in workplace practice.

We would not anticipate deploying across all areas of a large building at this stage - we are not sufficiently resourced to deploy large numbers of sensors and devices to view the application but a couple of different areas would be interesting to compare - for example a public ward and an open plan office (c 10-50 desks) . It would also be possible to deploy in one or two areas of the building in a first phase and then to redeploy in two further areas of the building in a second phase.

We are interested in exploring how e-genie can assist with co-managing comfort conditions in both summer and winter so there is no necessity to run the application solely during the heating season.

Technical needs
To produce the visualisations in the *energy consumption dashboard* and *temperature calendar*, e-Genie needs to capture data about the energy consumption of the building and resulting temperature in different parts of the building. This data is stored on the e-Genie server, allowing the organisation to access it via standard web-browsers on workplace computers, and on tablets supplied by C-tech that can be placed strategically around the building.

Installing sensing equipment
If the scope of the deployment includes the temperature calendar, we must install temperature sensors in the workplace. These sensors are small, battery-powered thermometers that can be left on a shelf or stuck to a wall, and periodically send temperature readings back to a central hub. Multiple temperature sensors can be deployed in one building: this is recommended if temperature varies significantly between spaces. The central hub is a small, mains-powered computer (Raspberry Pi) that requires an internet connection to pass the temperature readings back to the e-Genie server. If appropriate, this connection can be via the workplace network; alternatively the hub can be connected to the internet via a mobile internet dongle.

Installing energy monitoring equipment
If the deployment includes the energy consumption dashboard, e-Genie requires access to electricity consumption data from the building. A non-invasive way to achieve this is to make data from an existing BMS accessible to e-Genie. Whether this is possible is dependent on the particular model and configuration of the BMS, and so will require assessment by the e-Genie team. If existing consumption data is not available, it may be possible for the e-Genie team to help install new energy monitoring equipment. This equipment must be physically clamped to electricity cabling within distribution boxes in the building, and so a certified electrician must carry out this process. Each new piece of electricity monitoring equipment must be physically connected to a central hub, which will typically sit within the distribution box. This hub requires mains power and access to the internet to pass electricity readings back to the e-Genie server.

Installing e-genie on organisation's IT system
e-Genie is a web application hosted on our own web servers. This means that it can be accessed by a standard web-browser from computers, tablets or smart phones, without installing any new software in the workplace. Depending upon the needs of a particular deployment, we are able to limit access to devices on a particular workplace network, or to a particular building or set of devices, preventing access outside the workplace. In every deployment we will need to work with the organisation's IT managers to ensure e-Genie collects data and is accessible in a way that meets all relevant IT policies and procedures.

Next steps

Hopefully this note gives sufficient detail for [your organisation] to review internally and make a decision to take the next steps for involvement with this valuable research project. If [your organisation]does want to participate we would expect to have further phone meeting to clarify [your organisation] needs and then to come to site to understand your workplace's infrastructure, practices and technical requirements as per the deployment process outlined above.

Further information
Please contact XXX for further information at: