OfficeWise: energy feedback in office workplaces

Magdalena Boork
SP Technical Research Institute of Sweden
JTI, Box 7033
SE-750 07 Uppsala
Sweden
Magdalena.Boork@sp.se

Sander Dijkhuis
Interactive Swedish ICT
Portgatan 3
SE-633 42 Eskilstuna
Sweden
mail@sanderdijkhuis.nl

Anton Gustafsson
Interactive Swedish ICT
Portgatan 3
SE-633 42 Eskilstuna
Sweden
anton.gustafsson@tii.se

Cecilia Katzeff
Interactive Swedish ICT
Portgatan 3
SE-633 42 Eskilstuna
Sweden
cecilia.katzeff@tii.se

Keywords

visualisation, offices, feedback, user behaviour, management factors, energy saving potential

Abstract

This paper presents the approach, progress and intermediate results from a project on energy feedback in office workplaces carried out in Sweden in 2011–2014. A system of three energy visualization prototypes targeting office workers has been designed and implemented in an office workplace. Feedback is given both on individual basis (in a PC application) and on collective basis (on a screen in the reception and by an ambient representation in the lunchroom). A measurement system provides detailed data on individual electricity use, temperature, ventilation and presence. The project aims at engaging office workers to more energy efficient behaviour by supplying tools to raise the awareness and ability to take action, but also to implement energy feedback in organizational processes. The main goal is permanent behavioural changes, resulting in 50 % electricity reduction in individual office rooms.

The project is built on a participatory approach. The visualization tools were designed in collaboration with office workers using interviews, cultural probes, co-creation workshops etc. Designing new organizational strategies and action plans will include further workshops and co-creation with staff and management.

In spring 2014, a one-week challenge was conducted among the office workers to estimate the energy saving potential. The results show an average reduction of 32 % compared to a representative 'normal' week. On an annual basis, the savings correspond to 65 kWh per office room or 17 % of the total electricity use. In general, the participants found the challenge interesting and took the opportunity to look over their habits.

Throughout the project, office workers have stressed that the management lacks focus on and appreciation for energy efficiency. The next step is therefore to analyse how energy feedback can be implemented in organizational processes to achieve long-term changes in energy-related routines and behaviour.

Background

Research on people's energy use has so far primarily focused on households (Schwartz et al., 2010; Hargreaves, 2011; Katzeff et al., 2013). Employees are also part of different types of households. Still, the energy-related behaviour tends to be different at home and at work. Although the potential energy savings are significant, research focused on how knowledge provided by energy visualizations can be used at workplaces is scarce. However, there are some studies experimenting with games (Simon et al., 2012), ambient visualization (Katzeff et al. 2013) and social media (Lehrer and Vasudev, 2011) to increase the awareness of energy consumption in the workplace.

Energy use at workplaces is often associated with productivity and necessary working tasks. But there is also unnecessary energy use, such as computers and lighting turned on when no one is present, in this project called 'absence electricity'. This electricity use does not serve any purpose and therefore constitutes a considerable energy saving potential. The responsibility for energy use at office workplaces is, however, not always obvious. Management seldom focuses on energy saving routines, while employees lack motivation and a sense of responsibility since energy savings are rarely rewarded (Vasakronan, 2014;

Jain et al., 2013; Katzeff et al., 2013). Energy visualizations can increase the attention and discussion on energy issues, but it is not enough to achieve lasting and sustainable practices. Instead, the workplace routines need to be modified as well. A change to more pro-environmental behaviour, habits and practices in a workplace environment encounters severe challenges for the organization and its culture. From their studies of energy visualizations in the workplace, Katzeff et al. (2013) concluded that strong leadership is important when setting up change initiatives. These should be both top-down and bottom-up.

Research has shown that projects involving end-users in the design of new visualization and feedback systems generate greater interest and commitment among the users, often followed by behavioural changes, see for example (Katzeff et al., 2012; Hargreaves et al., 2013), Still, Hargreaves (2013) found that household users eventually lose interest in the visualization monitors and behavioural changes beyond the initial were not achieved. Similar conclusions were drawn from experiments with visualizations in office workplaces in Katzeff et al. (2013), where energy feedback was given for individual appliances at four different office workplaces. Interviews showed intensified discussions regarding the feedback, which made hidden workplace routines visible and also encouraged behavioural changes to some extent, but also that individuals have difficulties taking actions based on the provided feedback. This outcome inspired the OfficeWise project to take energy feedback beyond visualization and also focus on organizational structures and routines to achieve permanent changes in energy-related behaviour.

This paper presents the first phases of the OfficeWise project, focusing on the design and development, implementation and test of a system of electricity visualization prototypes for office workplaces. It also describes the coming project phases briefly.

AIM

The project aims at exploring the possibilities for office workplaces to turn energy feedback into action by supplying energy visualization tools, but also by implementing energy feedback in organizational processes. The main long-term goal is permanent behavioural changes, resulting in 50 % reduction of so-called absence electricity (or waste electricity) in individual office rooms. The first project phase focused on developing and implementing a system of electricity visualization prototypes addressing different types of feedback on both individual and joint electricity use. The coming project phase focuses on how organizations can incorporate and translate energy feedback into action to achieve sustainable practices. The main research questions are:

- How can organizations integrate feedback on workplace electricity use in new sustainable practices?
- How can different visualization types be combined to increase readiness to take action?

Approach

The OfficeWise project uses a participatory design approach to involve the end-users in the design process and in the project. The general form of this approach is to involve real or potential users from the start of the design process. Their ideas and needs are catered for in the creative early phases of the process and in the later phases their evaluation of the system certifies its usability and user quality. A participatory design approach is a specific case of a user-centred design methodology, which usually contains four distinct phases (ISO, 1999):

1. Understand and specify users and their context of use.
2. Specify the user requirements.
3. Produce design solutions.
4. Evaluate designs against requirements.

In the OfficeWise project, interviews and workshops were used for phases 1–3. In phase 4 the interaction between users and visualization prototypes were observed individually.

Test site and visualization prototypes

The project was established when a new floor comprising 30 office rooms and a meeting room was planned for an existing office building at SP Technical Research Institute of Sweden in 2010. Both office rooms and meeting room were equipped with advanced measurement and control systems for heating, ventilation, lighting, electricity and presence to enable detailed evaluation and feedback. All offices are equipped with presence controlled ceiling lights, turning off after 15 minutes. Apart from the new offices, the building comprises another 60 conventional offices, meeting rooms, as well as large laboratory facilities. The laboratory has been excluded from this study due to its energy intensive character.

The initial phase, focusing on participatory development of energy visualization prototypes, involved all 90 employees and in particular 15 of the new offices for individual energy feedback. Most employees perform different work tasks within the energy field; usually both office work and laboratory work, and business travels are common. Therefore, the average presence time in the office rooms is 4 hours 45 minutes.

Thus, the office does not represent an average office workplace, but the major advantages as a test site are:

1. The advanced in-built technical measurement systems.
2. Employees could share their energy skills and interest in the participatory co-creation design process.
3. Considerable technical understanding among the users will more clearly point to the barriers to become an energy efficient office, i.e. obstacles related to motivation and social structures rather than knowledge about energy and energy related actions.
4. Employees experienced a mismatch between the daily work in energy efficiency with costumers on the one side, and a lack of addressing energy efficiency issues within their own organization on the other.
5. The solar electricity production is continuously measured and logged since the installation of a PV solar shading system in 2013. It has therefore been possible to investigate the possibilities of using solar electricity production as a motivator for energy efficient behaviour.

DESIGN PROCESS

The initial work was focused on mapping the workplace culture and routines, as well as the employees' freedom of action, such as energy consuming activities performed during an ordinary workday and possibilities to influence those activities. The mapping was mainly based on cultural probes methodology (Gaver, 1999), where eight employees were asked to describe their working day in words, sketches and photos. The mapping was followed by design and co-creation workshops:

- Early 2012 a workshop was held with other employees, taking its starting point in the results from the cultural probes, to further agree on needs and co-create a first draft of concept for energy visualization.
- To refine the concept a design-workshop was also held with design-skilled colleagues.
- A co-creation workshop was held with employees early 2013 to develop ideas on a screen-based visualization on joint energy feedback.

Additionally, three installation events were arranged, one each time a new visualization prototype was released. They were used both to inform about the project and to create a feeling of involvement among the employees.

Apart from continuous feedback from users, two main evaluations have been performed so far. In late 2012 interviews were carried out with 13 of the 15 employees with access to individual energy feedback, mainly aiming at prototype improvement. In spring 2014, the perception and usefulness of the artistic prototype (Super Graph, see below) were evaluated by a questionnaire (21 responses) and a competition in saving absence electricity was evaluated by measurement data collection as well as a questionnaire to the 8 participants.

Some recurring themes have played particularly important roles in the design and development of the visualization concepts and prototypes, namely:

- **Competitions:** The employees are triggered by competitions and find it an attractive approach to draw attention to one's own energy use.
- **Rewards:** Collective rewards were considered more desirable than individual ones. Sweets for the coffee or installation of PV modules in relation to the attained total savings were suggested. For individuals, attention from co-workers and the management would be sufficiently rewarding.
- **Technical presentation:** Most employees have a technical background and asked for well-known presentations of the energy use, e.g. in graphs and key figures.
- **Absence electricity:** A contradiction between carrying out work tasks and saving energy has often been experienced. Additionally, employees need different equipment to carry out their tasks. To create a sense of fairness, the project focused on energy used when no one is present.
- **Image-building:** Working with energy efficiency, employees wanted to show customers and visitors that they 'practice what they preach'.

SYSTEM OF VISUALIZATION PROTOTYPES

The project has generated three major visualization prototypes. Two of the prototypes (one screen-based and one physical/artistic) focus on the collective electricity use and related information of common interest, while the third (screen-based) prototype provides feedback on individual basis.

The Super Graph

The artistic, ambient visualization prototype, the Super Graph, was produced in co-creation with the employees. The metallic frame, with its icons representing different energy-consuming equipment and activities at the workplace, as well as avatars in different colours and body expressions were produced based on the outcome of design workshops with a group of employees. An installation event was then held, where all 90 employees were invited to take part of the mounting of avatars onto the frame, see Figure 1.

The Super Graph hangs from the lunchroom ceiling as a "chandelier" and is attached to a counter-weight in the shape of an over-sized ruler, se Figure 2. As the total office power usage increases or decreases, the Super Graph moves vertically, and the absolute use can be read from the ruler. Employees usually visit the lunchroom several times per day. The idea of the Super Graph is to both constitute an ever-present symbol of the electricity use and generate discussions, and to be an interesting and attractive display object for visitors.

Figure 1. The ambient energy visualization prototype, the Super Graph. Left: All employees were invited to choose and mount an avatar representing themselves on to the chandelier. Right: The final appearance.

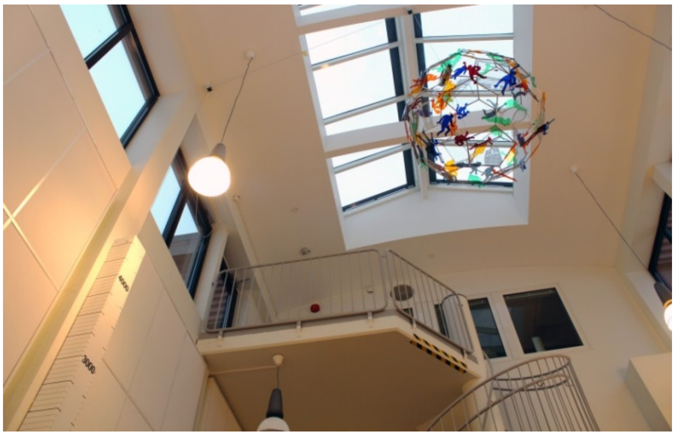

Figure 2. The 'chandelier' representing the total electricity use in the office building. The counter-weight in the shape of a ruler can be seen on the wall to the left.

Energy Intelligence

The touchscreen-based prototype Energy Intelligence offers detailed information about the total electricity use, the total absence electricity, PV power production, ongoing competitions etc. with the option to add other types of information, see Figure 3 (left). The idea is that Energy Intelligence is complementary to the Super Graph by offering a chance to explain and analyse the movement of the chandelier. The screen is located in the reception to be highly visible, since every person entering the building passes the reception.

Instant Energy

Instant Energy is a desktop application aiming to provide information on each employee's individual electricity use. The application was developed based on the outcome of design workshops with employees, which resulted in a technical appearance with graphs and statistics, see Figure 3 (right). The user may compare its electricity use to that of colleagues. However, for privacy reasons, each employee can choose to be invisible to others, and then cannot see the other's usage either.

Instant Energy offers information on instantaneous power use in the office room, detailed information on the individual power demand curve, presence and key figures for daily/weekly/monthly electricity use during presence and absence respectively.

The idea is that Instant Energy supplies the primary feedback to the users on their individual progress in competitions etc. The application has so far been used by the employees to explore their different electricity consuming equipment, find extraordinary occasions and compare their own normal consumption level with that of others to explore possible reasons for differences between similar offices.

Test with users: energy saving challenge

Since the periods of absence are significant at this workplace, electricity used during absence has so far been the main focus. To estimate how much of this waste electricity that can be saved, a one-week challenge in reducing the 'absence electricity' was conducted in spring 2014. All 15 office workers with access to Instant Energy (i.e. individual electricity data) were invited to participate. A drop-out, mainly due to business trips and leave of absence, resulted in 8 active participants. However, the presence is considered representative of a normal week.

All participants were informed about the challenge, normal and extreme levels of electricity use as well as how the two prototypes Instant Energy and Energy Intelligence could support them during the challenge. Information was given both orally and in writing. A joint goal of 40 % reduction was agreed upon and a reward, in terms of sweets for the coffee, to all employees was promised if the target could be reached. The project group did not interact with the participants during the challenge, but was available to support them.

The challenge was evaluated in two steps. Firstly, the electricity data from the challenge week was compared to a representative normal week on individual basis as well as in total. Every employee was compared to him/herself and the participant achieving the greatest relative reduction was announced 'the energy saver of the week'. Secondly, the participants filled out a questionnaire dealing with the challenge and ideas for future work on energy efficient behaviour at the workplace. The results from the challenge, including giving attention to 'the energy saver of the week', were communicated to all 90 employees by an information email as well as at a joint coffee gathering. For details about the challenge, see Gustafsson et al. (2014).

Results

ENERGY SAVING POTENTIAL

Measurement data analysis showed that more than 50 % of the total electricity used in individual offices during a normal week is used when no one is present, i.e. absence electricity. During the challenge, the participants reduced their power needs from in average 42 W to 29 W during periods of absence, which corresponds to 32 % reduction compared to a normal week. Since the average presence in those offices is 4 hours 45 minutes per day, this corresponds to an average daily energy saving of 0.26 kWh per office room, or an annual energy saving of 65 kWh[1] per office room (even more if weekends and holidays are included). The savings correspond to 17 % of the **total** electricity used in the office rooms.

It should be noted that the offices in this study are already energy efficient, making use of presence and demand control for ceiling lights, ventilation and heating. The power use during absence is therefore lower than most conventional offices. For example, measurement data from a few offices in the old part of the building as well as a few offices in another building with technical but not energy technology activities were analysed, which showed power usages of up to 110 W during night-time, compared to 3–10 W in the new offices. Observations indicate that there is a considerable difference in habits between the two workplaces when it comes to turning office appliances off when leaving for the day. This indicates a likeliness of even larger absolute energy saving potentials in conventional office workplaces.

1. Based on an average number of annual working days of 251.

Figure 3. The two screen-based visualization prototypes. Left: The touch screen-based visualization Energy Intelligence, located in the reception. Right: PC application Instant Energy on a desktop.

PARTICIPANTS' REACTIONS AND BEHAVIOURAL CHANGES

The energy savings during the challenge were significant, and to gain insight into what type of changes the participants chose to do to their energy-related behaviour a questionnaire was distributed right after the challenge week. A majority (80 %) found their participation worthwhile, and took the opportunity to reflect on their own energy use. Everybody considered themselves putting some effort in reducing their electricity use during the challenge. The major changes implemented by the participants, but also the habits they refused to change, are found in Table 1. It should be noted that changing the time of phone-charging is not an actual energy saving measure, but rather a time-shift, and the benefit is principally personal to accomplish the goal of the challenge, i.e. reducing the *absence* electricity. One participant wrote regarding his/her possible increased awareness:

> Yes, since this project was focused on this [absence electricity] I will keep in mind that it is indeed important and that it is unnecessary consumption […] But it doesn't matter when I charge my phones, it was just fun to do everything I could for the sake of the challenge!

The reasons mentioned for not changing possible energy saving habits, such as manually controlling the ceiling lights or completely turning off the PC, were primarily practical.

Conclusions and discussion

The project has mainly focused on the design of energy visualization prototypes suitable for office workplaces. The design process involved participation and co-creation with employees. Although all 90 employees have been invited to participate in the creative process, the main test group comprises 15 employees. The effect of individual measures and their interrelation for encouraging energy saving behaviour has not yet been studied. The next step is to make the prototypes available to a larger group of users, but also to other types of workplaces. Coming project phases will focus on long-term effects of energy feedback and organizational issues.

Still a few conclusions can be drawn:

- Comparable figures must be used in energy saving competitions and challenges to create a sense of justice. So far, absence electricity has been used as such unit.
- Absence electricity constitutes more than 50 % of the total electricity use in individual offices, and the energy saving potential associated with behavioural changes during absence was measured 17 % of the total electricity use. The absolute energy saving potential in conventional offices is likely even larger.
- A simple and cost-effective measurement system must be available for energy feedback system to be used in conventional offices outside a test site. Development of such systems has been initiated.
- There are considerable differences between workplace routines and organizations. In the project continuation, the prototypes will be implemented and evaluated in at least one more workplace.

Future outlook

Although users considered the system of prototypes valuable, they also experienced a feeling of helplessness. The space of freedom to act upon the feedback was experienced as limited, both when it came to choosing new office equipment from a predetermined set of devices and influencing energy consuming activities in the daily work. Moreover, energy saving activities were not rewarded by the organization. It was also frustrating not being able to judge which types of energy saving activities that would be meaningful and have an effect.

The above results and other studies (Katzeff et al., 2013) point to a lack of knowledge concerning the transition from the visualization on energy consumption to practical action in organizations. There seems to be a gap between feedback to employees and the organization's ability to take care of the feedback and implement the knowledge into practical organizational processes. More research is needed to consider the relationship between organizational structures and processes, with a focus on the interplay between the organization, workplace practices and the energy visualization. Katzeff et al.

Table 1. Changes that the participants chose to implement and not to implement during the challenge in reducing the absence electricity.

Changes implemented by the participants	Habits that participants chose not to change
Put PC and monitor in energy saving mode, manually or by changing the settings	Completely turn off the PC during absence periods during working hours
Charge the phone during presence instead of absence	Manually control the ceiling lights

(2013) suggest that the implementation of energy visualizations in an organization must be regarded as an organizational change similar to the implementation of any new technical system. Consequently, a successful implementation ought to apply established knowledge in the domain of the implementation of organizational change. A strong leadership emphasizing the importance of prioritizing the change, even if it intrudes on the daily work, is considered to be crucial. Another issue for future research is how energy visualizations in workplaces may be used as pedagogical tools to encourage a change into more sustainable practices. Knowledge could thus be developed to be integrated into organizational processes through action plans and general recommendations concerning energy visualizations at workplaces.

References

Gaver, W., Dunne, A., Pacenti, E. (1999). Design: Cultural probes. *Interactions* 6 (1), 21–29.

Gustafsson, A., Boork, M. (2014) *Slutrapport projekt 37061-1: Ett levande labb – Framtidens energianvändning i kontorsmiljö.* Swedish Energy Agency. In Swedish.

Hargreaves, T. (2011). Practicing Behavior Change: Applying Social Practice Theory to Pro-Environmental Behavior Change. *Journal of Consumer Culture* 11 (1) 79–99.

Hargreaves, T., Nye, M., Burgess, J. (2013) Keeping Energy Visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. *Energy Policy* 52, 126–134.

ISO (International Standards Organisation). (1999) *ISO 13407: 1999 Human-centred design processes for interactive systems*. Geneva.

Jain, M., Agrawal, A., Ghai, S., Truong, K., Seetharam, D. (2013). "We are not in the loop": Resource Wastage and Conservation Attitude of Employees in Indian Workplace. *UbiComp'13*. Zurich, Switzerland, September 8–12.

Katzeff, C., Nyblom, Å., Tunheden, S., Torstensson, C. (2012) User centred design and evaluation of EnergyCoach – an interactive energy service for households. *Behaviour and Information Technology* 31(3), 305–324. Special issue on "Services and Human-computer Interaction. New opportunities". Taylor & Frances Group.

Katzeff, C., Broms, L., Jönsson, L., Westholm, U., Räsänen, M. (2013) Exploring sustainable practices in workplace settings by visualizing electricity consumption. *ACM Transactions on Computer-Human Interaction* 20 (5), article 31.

Lehrer, D., Vasudev, J. (2011). Evaluating a Social Media Application for Sustainability in the Workplace. *CHI2011*, Vancouver, BC, Canada, May 7–12.

Schwartz T., Betz M., Ramirez L., Stevens G. (2010) Sustainable Energy Practices at Work: Understanding the Role of Workers in Energy Conservation. *Proceedings of NordiCHI 2010*. Reykjavik, Iceland, October 16–20.

Simon, J., Jahn, M., Al-Akkad, A. (2012). Saving Energy at Work: The Design of a Pervasive Game for Office Spaces. *MUM '12*. Ulm, Germany, December 4–6.

Vasakronan. (2014) Kontorsbarometern. *www.kontorsbarometern.se.* Last accessed 2015-03-01. In Swedish.

Acknowledgements

The authors would like to thank RI.SE and the Swedish Energy Agency for funding the project and all employees for their creative ideas and commitment.