Sustainable Energy Practices at Work: Understanding the Role of Workers in Energy Conservation

Tobias Schwartz, Matthias Betz, Leonardo Ramirez, Gunnar Stevens

[1]Fraunhofer Institute for Applied Information Technology, Schloss Birlinghoven, 53754 Sankt Augustin, Germany

[2]Human Computer Interaction, University of Siegen, Hölderlinstraße 3, 57068 Siegen, Germany

{tobias.schwartz, matthias.betz, leonardo.ramirez}@fit.fraunhofer.de
gunnar.stevens@uni-siegen.de

ABSTRACT

Energy conservation has become a very relevant social issue. There is a growing body of knowledge in the literature focused on supporting consumers in reducing their personal carbon footprint in their domestic context. In the workplace, however, most of the research focuses on optimizing formalized production processes and investing in energy efficient equipment. This leaves the question open of the role of workers in energy conservation. To explore this question, and overcome this bias, we conducted a series of participatory action research studies in which we introduced new smart metering technologies in a large organization and observed their contribution in supporting sustainable energy practices at work. In the paper we discuss the opportunity and risks posed by using this technology to make energy practices more transparent.

Author Keywords

Energy conservation, sustainability, practices, workplace, emancipation

ACM Classification Keywords

H.1.3 [Information Systems]: User/Machine Systems – human factors

INTRODUCTION

In the last years, energy consumption has become an important social issue, leading to a growing awareness of personal responsibility in preventing environmental pollution, minimize the waste of energy and reduce the carbon footprint.

Workplaces are no strange to this development. The accelerated grow of IT and electronic devices usage in the last 20 years has changed office work dramatically. There are virtually no chances of having a productive workplace without the support of electrical appliances such as computers, printers, or telephones. With the exception of the manufacturing sector, almost 30% of the total energy consumption of a company is produced by the office equipment.

If we take into account the fact that in the last 50 years in Germany, the proportion of office workplaces in the overall amount of consume points has risen from about 10 percent to about 50 percent [14], it becomes clear that supporting energy conservation in the office represents a key challenge for post-industrial societies.

Many efforts in research have addressed this challenged, building technologies to support energy conservation and sustainable development. Smart grid technologies, for example, should stimulate the efficiency in consuming electrical resources by using a combination of advanced communications, sensors, and distributed computer-based controllers that support network management. Sensor technologies that keep a digital record of the energy consumption of individual devices or complete households should support the personal awareness of energy consumption.

All these new digital metering solutions provide tools for measuring, structuring, transferring, storing and visualizing consumption data, creating a promising new field of applications for the HCI community [10], which has consequently focused on building better and more intelligent monitoring and visualizing technologies with aimed at increasing awareness for consumers and producers, and at providing control mechanisms to empower consumers to make more informed energy choices.

In the workplace, energy conservation has been mostly studied from the perspective of organizational strategies, and only few studies take a situated, self-organized understanding of work practices into their conceptual and constructional considerations.

NordiCHI 2010, October 16–20, 2010, Reykjavik, Iceland.
 ISBN: 978-1-60558-934-3...$5.00.

At this point, this research falls behind the insights reached by the CSCW and Participatory Design communities, both of which argue that situated work practices cannot reduce to formalized work processes. Hence, the worker should be included in the conservation strategies as an active participant for normative as well as analytical reasons. In order to overcome that bias in research and to explore the development of energy conservation practices in the workplace, we conducted a participatory action research study in a German organization, focused on the interplay between personal behavior, the surrounding conditions and supportive technologies.

To provide a frame encompassing our need for a perspective taking both normative definitions as well as individual action, we use methods taken from the Business Ethnography approach [20]. This approach provided us with an analytical as well as a normative lens, both providing categories to understand the process as well as directions to organize our research.

In the study, we recorded the energy consumption of two bureau offices and fed the data back to the workers. The data was then used to discuss existing energy practices and options to change them. This work produced then a collection of qualitative results that was used to prepare and conduct an organization-wide survey. The survey also included question addressing organizational issues using energy monitoring technologies on the workplace.

The paper is structured as follows. First we describe the framework used to foster emancipative practice at work. We then describe our field of application and our findings. At the end we discuss the case regarding to the opportunities of Participatory Design approaches in the context of sustainable development and implications for designing supportive tools.

THE DIALECTICS OF ENERGY CONSERVATION

Organizational strategies for Energy Conservation

Organizational strategies aim at reducing consumption through the creation of energy-efficient production processes by leveraging energy-saving equipment and centralized energy management.

The role of IT in this process is double-folded. On one side, IT represents a large focus of energy consumption and hence, it becomes a target for energy saving measures. On the other side, IT provides valuable resources for the analysis and management of sustainability.

The concept of Green IT, which has become popular in the last years, addresses both roles of IT in providing a frame to manage sustainability. Green IT refers to activities concerning sustainable IT resource management from an ecological perspective, covering the whole life cycle of "designing, manufacturing, using, and disposing of personal computers, servers, and associated subsystems such as monitors, printers, storage devices, and networking and communications systems" [18]

In general, there is a high expectation to save energy through organizational measures. Studies conducted by the German Energy Agency dena highlight that investments in the infrastructure has a high saving potential. Workplaces equipped with energy-efficient infrastructure could save up to 75 percent of electricity costs compared to inefficient equipped workplace. Yet the majority of companies still haven't found organizational strategies to materialize this existing potential.

A study reveals that the main barriers for companies were the lack of financial resources as well as of knowledge [25]. 36 percent of companies, who haven't initiated energy conservation strategies, say that financing of energy efficiency measures are the greatest challenge for them. Additionally, 32 percent of companies noted that they do not have enough information to make competent decisions in the area.

One shortcoming of approaches taking an organizational strategy is that they often focus on the management level only, disregarding the ability of situated work practices to produce tactics that might need less capital investment, but have a bigger impact in energy consumption savings. Typically organizational approaches observe the problem at a granularity that leverage the organizational equipment and processes from a top-down perspective.

Pettersen and Boks note, however, that to allow sustainable development means that "consumption patterns must be changed" [21]. A strategy aligned with this form of thinking calls for changing the situated work practices within the given organizational conditions at the level of each and every worker.

Situated work practices

Support for behavior change in energy efficiency has been researched extensively in the domestic field. Feedback for better awareness or control of energy usage is studied in several surveys [3,9]. In the last decades a variety of activities with focus of feedback on electricity consumption were conducted [10,17]. Darby for example gives an overview of papers and researches related to the topic metering, billing and direct displays. She concludes in her report that clear feedback is a necessary element in learning and allows energy users to teach themselves through experimentation. Energy saving potentials between 15%-20% could observe through the usage of feedback infrastructure [9]. She argued that especially a higher transparency and individual feedback can influence energy consumption essential in a positive way and increases the potential of energy savings [8,9].

The results of Chetty et al. [6,7] support this statements. She fed energy consumption measurements in households to the consumers to support ongoing self-learning processes. The results report modifications of behavior in

households equipped with home infrastructure for resource conservation.

Contrasting with the situation on the field of domestic consumption, there are only few studies focused on the opportunities of the new metering technologies to support the energy consumption awareness and change of behavior in the workplace. One of the few exception is the study of Siero et al. [24]. They focus especially on the changing of organizationally energy consumption behavior through the instrument of cooperative feedback. They conduct a study where they provided feedback to two different organization units with the different that one unit only gets information about their own energy consumption and the second unit additionally gets information about the saving from the other unit. The results clearly showed that employees in the comparative feedback condition saved more energy than employees who only received information about their own performance, even half a year after the intervention. A remarkable finding was that behavioral change took place with hardly any changes in attitudes or intentions.

The work of Siero show the relevance that situated approaches can have for energy conservation systems, although his effort remains at a collective level, leaving the question open, of getting closer to the practice of each situated worker.

Emancipatory practices for energy conservation

Fogg [12] has suggested the concept of persuasive technologies, which focuses on the goal of changes of behavior by means of using pervasive computing. Persuasive technologies are concerned "with how behavior modification can be induced by intervening in moments of local decision-making and by providing people with new rewards and new motivations for desirable behaviors" [13].

The merit of approaches such as persuasive technologies is that they emphasize the question of practice development in evaluating technology, beyond criteria such as usability or ease of use. Although interesting, the concept faces the danger of reducing action to a single-sided personal decision-making, neglecting the dialectic quality of practices as both medium and outcome, shaped by the dominating socio-historical conditions.

It is not just a coincidence that the concept of persuasive technologies is applied only in areas dominated by individual decision making, such as personal health, but that it remains less explored from areas dominated by alienation, which is the case of the workplace.

In the Participatory Design Tradition, the development of artifacts and work practices are constituents of a dialectical unity that deals *"with the contradiction between tradition and transcendence"* [11]. The ambition of PD to include users in the design process is not limited to requirements elicitation. Instead, in the process of evolutionary growth of users and artifacts, the broader goal of PD is to empower users both cognitive as well as materially.

This goal provides us guiding principle to design and evaluate technology, serving as a tool for emancipation. However going back to the roots of the Age of Enlightenment, empowerment as "man's emergence from his self-imposed immaturity" [15] means more than just to increase the opportunities for a self-determined life. Empowerment is also the obligation of making use of opportunities to act responsibly. The result of this dialectic unity to having power and taking the responsibility of the own life presents emancipatory practices in a truth sense [11].

In our research we adopted the considerations of Ehn of emancipator practices. Although the core can be kept, some new issues have to take into account applying the concept to the topic of sustainable energy practices at work. The original intention of PD was to design artifacts having the democratization of work in mind. Hence the goal was to increase the autonomy of the worker and decrease the alienation resulted from capitalistic work conditions. Our intention is slightly different.

What we want to argue here is that energy consumption must be understood only as a symptom resulting from personal habits shaped by socio-historical conditions, and that supporting sustainable energy practices is much more about introducing changes in these habits and in the related socio-historical conditions of life. We want to pinpoint that both the role of normative organizational actions as well as individual action are just parts of the whole challenge of fostering behavior change into the direction of sustainable energy practices.

The normative stance of supporting workers in reducing the carbon footprint at work rest on the strong assumption that workers can and will take the responsibility of their energy consumption. To investigate if this assumption holds empirically and evaluate opportunities to change work practices reducing the energy consumption, we took an action research approach to study the energy practices of office workers and look for opportunities to change them.

This study follows the principle of Business Ethnography (BE), which we outline in the next section.

RESEARCH DESIGN

Business Ethnography

Business Ethnography is a participatory action research approach, with the goal of understanding everyday work practices in a particular context and supporting the development of these practices into more desired ones [19,20].

The process of a Business Ethnography is mainly based on a set of decision and reflection workshops conducted both by researchers and organization members, and focused on analyzing and defining requirements or on discussing design alternatives [22]. These workshops are complemented by ethnographic studies based on interviews

Figure 1: Provided device-based metering infrastructure handed out to the participants

as well as field observations, conceptualized as a visible intervention into the field established by the cooperation of the project partners and framed by the action research-oriented context.

An integral part of the BE is the collection and confrontation of comments from project partners with the analyses of the interviews conducted with them. The reason for this is two-folded. First this is a common method in action research to validate the analyses, which is adopted in BE. Second, this strategy is used to allow for the emergence of self-organized learning processes. The feedback confronts the interviewees with a perception of their situation that has undergone a methodological interpretation by the ethnographers that is made visible to the interviewees.

Presenting the participants their own practices from such a foreign angle creates a Brechtian distancing effect [4], leading to an alienation of the own experience that they expressed. This work of alienating the familiar allows the project to evaluate perceptions and expectations of the project partners from a distant position. This supports the discursive re-appropriation of the own activities given by the dialectic of tradition and transcendence.

BE also produces data for the analysis of learning processes. The alienation of the own experience is combined with common discussions of the interviewed partners about the validity of the interpretation and its impact for the understanding of the given situation and for the common project. This social process increases the distancing effect of the alienation/re-appropriation loop of BE in regard of the experiences of the interviewees in fostering knowledge development.

As a compound of action research and ethnography, the ethnographers cooperate with the project partners to achieve common project aims. Organizing an alienation/ re-appropriation loop of related knowledge with the project partners helps them to reflect on their local expertise and develop new strategies.

Field of application

The organizational units which took part in our study are members of a large international institute for applied research. At the place where the study was conducted more than 950 workers are employed in 4 different organizational units. The organization is structured hierarchically. Every unit is managed by a business segment department leader followed by group leaders who are responsible for smaller work teams. A strategic realignment or instruction has to pass these stations in the hierarchy. In the observed organizational unit a weekly team meeting is conducted in a room for discussions of actual topics, feedback and suggestions from the employees to organizational tasks.

Most of the employees on the operational layer are knowledge workers in different domains with a strong scientific background. They are sitting in single- and shared offices with a maximum of up to 5 or 6 persons. The predominant workplaces are single office.

Applied Methods

Our research activities can be split into four stages. In the *first stage* we established cooperation with 8 employees of two multi-bureau offices. We ask them for permission to monitor their energy consumption using off-the-shelf smart metering products and with their agreement, the campus janitor installed smart metering sensors in the fuse box for the two offices. The sensors logged the energy consumption of the two offices and sent this data to a PC (cf. Figure 4). With the help of this equipment we logged the energy consumption for 5 months between March and July of 2009.

In the *second stage* we carried out a "reflection workshop" with six participating employees; four of them were working in the offices which were subject to the metering activities in the last three weeks before the workshop took place. The other two were not involved in metering. In the workshop we fed the observed energy practices back to the participants and moderated a group discussion. In opposite to other BE projects [20] in this case we didn't use interviews but the logged data as the element for the alienated/re-appropriation loop.

In the workshop we asked participants to give comments and fostered a collective discussion among them following a two-folded research agenda. The first point we wanted to address with the workshop was to evaluate if the provided smart metering data was useful to identify saving potential and if the participants would react or change their behaviour in relation to the new transparency of their energy usage. The second element we observed during the workshop was the emergence of critical incidents showing hints to opportunities for a proper smart metering infrastructure in environmental context.

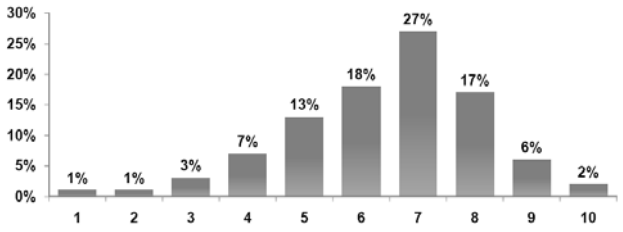

Figure 2: Distribution of self assessment on energy expertise on a scale of 1 to 10 in the organization

In the *third stage* we used the installed smart metering technology to study the effects of the reflection around captured data on the daily energy conservation practices. The participants asked in the workshops for additional options to measure energy consumption in a more detailed level. We followed this request and equipped the two offices with additionally smart metering infrastructure that could be used independent by the employees to measure energy consumption on a device level.

In the *third stage* we study the effects of reflection workshop on the daily energy practice. Therefore we monitor for two months the total energy consumption. In addition we observed device usage and interviewed the owners of the devices to capture any possible change in uses and behaviour.

In the *fourth stage* we conducted a mixed-method approach [16], were we complemented our qualitative study with a quantitative oriented online survey. The aim was to explore the significance of phenomena observed during the qualitative part of the study at whole organization level. We distributed an online-questionnaire consisting of 27 statements related to the topics of energy usage and the imagined usage of smart metering infrastructure in work environment.

We sent a list of question motivated by the experiences we made during the qualitative investigation. Additional space was given to the participants to add their own statements and suggestions. The online questionnaire was send to all workers of the institute composed of more than 950 people with a response rate of 17,5 %. 76% of the persons who participated at the survey added personal comments or suggestions. The information obtained was very useful for creating a better understanding of the organizational context and triangulated with our qualitative results.

FINDINGS

In the following we present the main findings of the conducted research. The findings from the qualitative group interview are discussed and compared with the results of the quantitative results from the online survey. With this, we intend to deal with the objection against qualitative action research accusing it of focusing only on exotic cases. In particular the survey helps to validate our impression that energy practices as well as the energy expertise of the participants in the qualitative studies are quite representative of the whole organization.

An ordinary office constellation

Concerning equipment, the survey shows that bureaus are similar and match the needed appliances for office work. Desktop PC, Monitor and Laptop were mentioned as the mostly used devices in the survey. This was confirmed by the central IT management for the rest of the campus. Samples show that often exactly the same appliances were used (same brand and type). Variations were present but not frequent and in the observed cases related to special tasks and roles.

The survey shows that currently no activities focusing on energy monitoring and control are established at workplace level. The self assessed energy expertise of the employees was relative high. In average they self-assessed their expertise on a level of 6,5 on a scale of 1 to 10 (1= very low, 10 = very high) (c.f. Figure 2). 47% of the participants know the average price of one kWh of electric power for private households. The answer “I don’t know what kWh means.” was not selected by any of the participants. This result was in line with our qualitative results. E.g. in our interviews every participant was able to interpret the unit kWh and to interpret energy plots like in Figure 5. We only observed problems in breaking down the kWh unit to a 5 minute scale. (We converted the presentation of kWh to 60 minutes intervals which made the presented consumption easier to compare with private power consumptions known from bills, tariffs etc)

Based on the survey, and considering equipment, energy expertise and energy conservation practices, the results show that the participants of the qualitative study are on a similar level as the average member of the organization.

Workshop on consumption reflection

To further understand and analyze the participants’ perception of their personal and common energy consumption we confronted the participants with their own energy practices in the workshop described above. After a short introduction and description of the setting, the workshop moderator presented a graphical representation (c.f. Figure 5) of the energy consumption based on measurements made during three weeks right before the workshop to foster the group discussion. Based on the presentation the moderator explained the granularity of the measurements in relation to time. The presentation allowed zooming into the graph up to a resolution of consumed kWhs in 5 minutes slots. This feature of the presented visualization enabled all workshop participants to look deeper into details if necessary.

Recognition of Patterns

After clarifying questions about units and granularity of the measurement in the shown visualization, the participants started with an interpretation of the ascertained consumption. Early in the beginning of the group

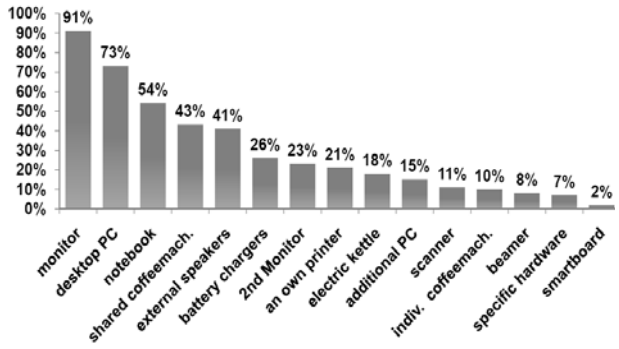

Figure 3: The most used electronic equipment used in the offices

discussion, one of the participants recognized patterns in the consumption:

A: "Isn't there a huge base load [Break] 50% of our consumption is on a base load level! [Break] But that also means our real consumption is not that high [laughing]. You know what I mean? That's somehow good!"

Then, the other participants picked up the point and started a discussion about the composition of the base load. They listed AC adapters, PCs which are switched off in the evening, battery chargers, a shared stereo, a locally installed test-server (an old desktop PC), a large interactive display, etc. The participants recognized that the base load on weekends is lower than during the week. They explained this by relating it to the switching off of some of the devices on Fridays, like the stereo and the desktop PC. However, during this workshop it was not possible to clarify which devices caused which amount of base load because the installed metering solution does not log the data in such granularity.

Even considering that there are no economic consequences for the participants they experience devices unnecessarily running as a waste. This was the subject of several statements in the conversation, e.g.

A: "The stereo… When I arrive in the morning and I see that the stereo is still switched on I feel bad about it. Because we did not switch it off. [Break] Well, I switch it off, usually. Consciously. Because I sit there next to it."

B: "I also always switch the stereo off. Well, if I am the last one here in the evening. Then I switch the stereo off.

C: "I do not care about it. Is not on my personal space… behind the desk. On the other side."

B: "You do not use it, also."

Figure 4: The structure of the device-wise smart metering infrastructure to log the energy consumption deployed in the offices

Based on this conversation we also included a question in the online survey regarding the usage of devices which probably cause base load and consumption. As illustrated in Figure 3 the used equipment and devices in offices can be very diverse and manifold.

Mapping to real world events

In progress of the discussion the participants tried to identify the consumption they caused personally. Usually every one of them starts working areound 9:00am but on a certain day participant A started earlier at 7:00am. After checking the personal and the group calendar and after some searching and zooming into the graph participant A identified a peak in the early morning. Doing so he mentioned:

A: "There it is! The peak that I caused! This morning I used all the stuff I always use. The peak is my contribution to the big peak we cause together. [Break] Yes, that's me.!"

Further on, the participants continued to identify additional patterns. They recognized a lower load on the second weekend than on each of the others. They tried to identify which device could be switched off on that weekend. Participant B states:

B: "Probably I shut down my desktop PC on that weekend, but I am not sure. I think it is impossible to say something about it. There is no way of deriving something only from this small bit if information. It's all speculative in the end."

The discussion then develops into the interpretation of the consumption in terms of the behavior of the group and also of each individual. After a long period of remaining quiet, participant C asks in a provoking but friendly way:

C: " When do we start talking about who is guilty for the whole thing? I think 'B' is guilty. He really do not care about it, about the electricity.?

Interviewer: "Why do you think so?

C: "Because he plugs everything in. And if it's plugged, it will never be unplugged again. That's the rule."

A: "We have already talked about it. There was a situation when you or I said: 'Come on 'B' what about shutting down your computer over the weekend?'

B: "I use it sometimes from home. To log onto the remote desktop. That's a server for me."

A: "If you had a button 'Switch in server now', that would be ok, too."

B: "That would be perfect, yes."

A: "Then, you could switch it off. Always.

C: "That's something I can accept. That would be a good idea."

In the following discourse, the participants go step by step through a list of all devices plugged in the office, created by the moderator before the workshop. The list contains metadata collected from the rating plates about the nominal energy consumption of the devices. Based on the list it was much easier to get a feeling of how many devices each individual person uses and how much energy they need. During this discussion everybody argues that each device is necessary for their work.

Analyzing and interpreting the represented consumption

The discussion ends up in a very controversial dispute about the question, how the smart metering data could be used to implement adequate measures for energy saving in the organization. Within the group of participants there were obviously different positions about the comparison of each employee's energy consumption patterns.

> *Interviewer: "The leader of the unit appeals to you all, as responsible employees, with your competencies to contribute to the energy saving activities here in the organization."*
>
> *A: "Sorry, but this is naïve and infantile. [Break] Because there is no analys behind it."*
>
> *B: "We have already seen it here in this workshop. We have lots of data here. But the data makes no sense without information about the underlying behavior."*

The statement of participant B point out to the complexity and difficulty of interpreting smart metering data by the employees in their work context. Additionally the need of connecting measured values to activities and uses becomes more important in the discussion. Referring to that, one participant suggested using the existing group calendar to reconstruct activities and use that information to rate the smart metering information. The other participants agree to use the office group calendar to improve the semantic information of the given metering values. Simultaneously, they commented this information as not being enough to estimate all opportunities for energy saving potentials.

Later on, the participants discussed collaborative how they could improve energy saving activities in their office. One idea suggested by a participant was to provide energy consumption information on a device level:

> *B: "For me this is not helpful [Break]. I need something like a signal light [Break], then I can consider the usage appliance by appliance."*

Without any influence of the moderator on the decision making process within the group, the participants asked for technical support to measure the energy consumption on device level. As an outcome of the reflection workshop, we made simple "smart plug adapters" (cf. Figure 1) showing energy usage in watts available to the employees without further instructions of usage. The smart plug adapters were used independently by the employees in their offices.

Effects of the Reflection

The same setting of metering under changed conditions (smart plugs made available to the participants and the knowledge collected from the workshop) was conducted during the three weeks directly after the reflection workshop. As shown in Figure 6 especially the base load outside the main working time decreased evidently. By using the provided "smart plug adapters" the employees started to identify appliances with a high stand-by energy consumption, and started to turn them off.

In particular, the participants changed their behavior related to appliances less commonly used, such a special desktop PC used for video editing or a large interactive display with high base loads, both rarely used in the daily work activities. As a consequence of the reflection workshop the large interactive display was completely cut off from the

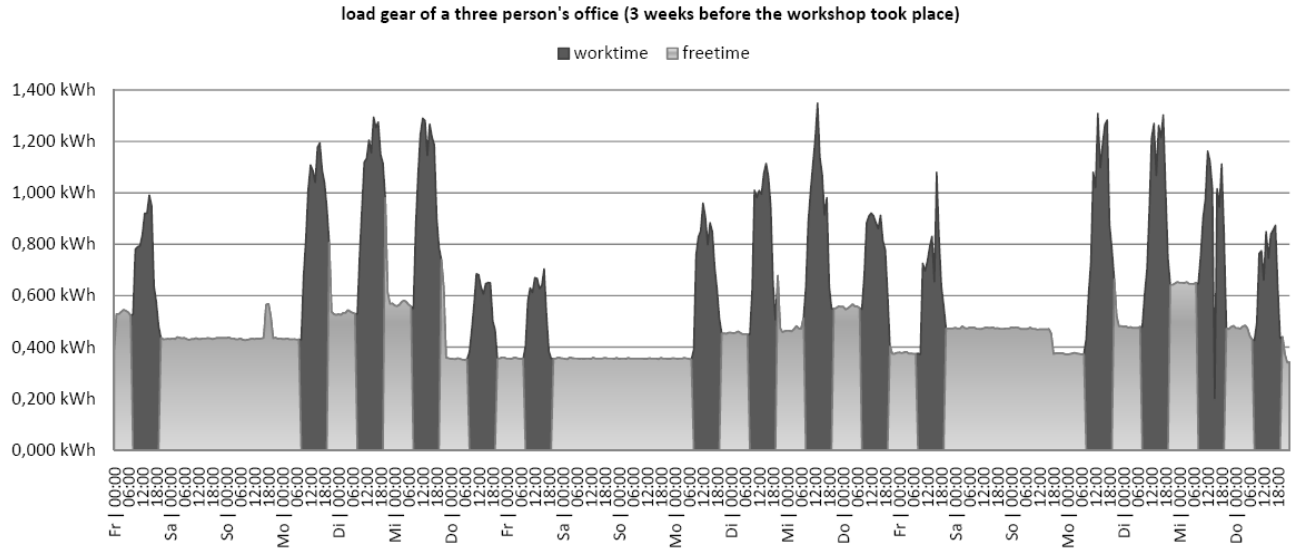

Figure 5: Load gear of a three person's office three weeks before the reflection workshop

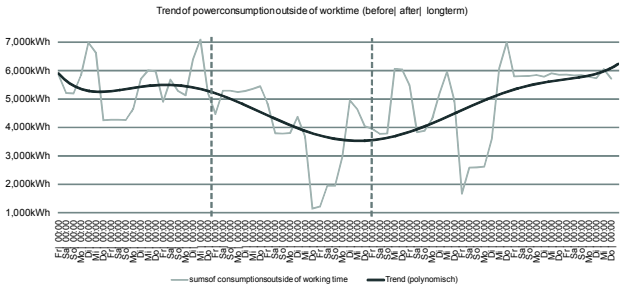

Figure 6: Trend of power consumption out of main working times over all three phases of investigation: three weeks before the workshop, three weeks right after the workshop and several weeks after

electrical grid. The video editing PC was configured to shuts down automatically after 30 minutes of being idle. Additionally, the participants of the workshop came to the commitment of cutting down the shared stereo amplifier from the grid at evenings and during weekends.

Contrasting the power consumption of the three weeks before the workshop and three weeks after the workshop, the consumption outside the main working time (7:30pm-7:30am) was reduced from 0.288kWh per hour to 0.217 kWh per hour in average. This means a saving of 24,9%.

To make the long-term effect visible, the measurement of energy consumption in the relevant offices continued for 5 weeks after the reflection workshop. Taking the consumptions outside the main working times into consideration the participants caused an average consumption of 0.264 kWh per hour during the last 5 weeks of the study. The measurements showed that the saving effects decreased over time. But still, this value is 8.4% less compared with the data before the workshop.

Figure 6 illustrates this phenomenon with the help of a trend line: The left interval represents the base data collected before the workshop; the interval in the middle shows the significant reduction right after the workshop. When consumption feedback was removed in the last phase, the interval on the right illustrates the rising consumption outside main working times. The result shows an interesting trend that might be characteristic for such constellations: All goals settled during the workshop are enforced directly after the workshops, but their effect tends to disappear on the long run, if feedback is removed. Without any further support, old habits come back which leads into an increment in consumption.

Organizational Issues

In the reflection workshop the participants often pointed out the special interdependences of the shown smart metering information in the organizational context.

Based on this connection, we formulated questions in the survey addressing the issue of providing smart metering information in work context. In the following we present a triangulation of insight from the workshop, the survey and observational findings.

Good to control - bad to evaluate

One problem of the usage of smart metering is that the activities of employees could be tracked very precisely, which probably causes privacy problems.

One participant compared his consumption profile to a time clock logging his presence in the office. The only pattern he could identify was activity versus non activity. He explained that how easy it would be for him to have a pretty good image of the times that an employee works or is at home.

Energy consumption could be used to control the activities of employees easily. The participants observed however, that drawing a conclusion between their energy consumption and their performance in the job is very difficult. Monitoring energy consumption is not the right instrument for assesing work performance, but there is a latent fear that it can be misused for this purpose.

One participant of the workshop pointed out that the energy consumption is not the central point. And that there is an different between energy consumption and energy waste. The argument was that the goal should be to bring the consumed energy together with the output in the job to calculate a performance.

Smart Metering Information is personal information

The survey pointed out that in some cases people are very strict in showing their personal consumption to colleges or other parts of the organization. They were afraid of the interpretation of the smart metering information from colleagues outside their immediate vicinity.

As reasons, the participants mentioned misinterpretations and the implicit evaluation of work performance. Also the uncertainty about of how this information could be used in organizational context was mentioned as a reason for an adverse position of employees. The empirical material showed that for some reason metering information was classified as a personal good, and the fact of loosing data ownership always comes with fears of misinterpretations.

In a more positive way of thinking, we observed the phenomena that the comparisons of individual consumption information are an innovative way to identify energy saving potentials. The approach of providing metering information only for selected colleges and not for the whole institution were proposed by the participants and showed up also in the survey results. The agreement with sharing this kind of information was bounded to the existence of a personal bond to the corresponding colleges. The participants pointed out, that they are interested in talking and discussing this information collective. But again, the own involvement in the interpretation process was an important

factor from a participant point of view to prevent misinterpretation.

In other cases persons were very happy about the new opportunity of smart metering information and understood this information as an instrument to contribute to the aim of energy saving and climate protection. For this group, the aspect of privacy did not play a role or is deemed less important.

Collective problem understanding and collective solution

In the organizational context there are several collective used appliances like printers, data projectors, fax, coffee machines, etc. This motivated the question of how the energy consumption of such collective goods can be optimized by providing metering information to the collective. This question implies the complexity arising from individual energy practices coming into conflict with each other or from responsibilities not being clarified.

In our study, we observed several cases for such collective use of appliances. In most of the cases the arrangement of collective appliance usage worked very well. However, we noticed that awareness about the energy consumption of collective or public goods was relative low compared to appliances in the area of personal responsibility. This low awareness had the effect that saving potential goes unnoticed. An example in our study was the practice of not switching off the large interactive display and stereo amplifier when not in use. This was not caused by an individual decision, but more a consequence of the absence of a collective planned action.

In the workshop the participants also negotiated and discussed possible solutions for collective used artifacts, such as cutting off the appliances from the supply grid to prevent the increase of base load. Another collective solution approach was posed by the office workers controlling each other regarding switching off the stereo amplifier before leaving their office. This practice proved to be substantial in reducing the base load during off- time. Our data demonstrates, however, that this was not a sustainable practice.

DESIGN ISSUES

The reflection workshop and its impact have demonstrated that the carbon footprint of an organization can be reduced by changing energy practices. In particular, the results emerging from our studies clearly showed that the interplay between energy consumption data and personal habits was the key for stimulating energy efficient behavior.

In design sessions held after the studies, we discussed the findings in terms of design supporting the change of energy practices. We present here two contrasting design concepts that address the challenge of supporting sustainable energy practices.

Improving the capture of behavior

One option to support change of habits is to capture and track the personal activities and integrate this information with energy consumption data. Unfortunately, modeling and tracking energy consumption habits is very complex and it is always in danger of misinterpreting the intention of the user (in particular in the case of collective goods). This is one of the reasons why ambitious smart home solutions fail in practice. However, weak structured approaches could support users reconstructing their behavior in the past for an ex post reflection and analysis of their energy consumption.

To support individual energy practices, one design option is to introduce a tool to capture and document personal carbon footprint in daily life (like a sensecam for energy monitoring [23]). Such a solution could record a photo streams that can be synchronized with energy consumption information. This will help users to recall certain situations and reflect on their in-situ decision process. Such an approach would allow the construction of histories which could form the basis for an ex-post analysis to stimulate learning and reflection and motivate change of habits in the future [5].

Provide energy consumption information in situ

Reconstructing context is very difficult. A complementary approach could be to provide information of energy during use. The situation is then enriched by direct feedback of current consumption. Energy use produces a breakdown in the activities of the users which motivates a reflection and has the potential of triggering a learning process. A possible implementation of this approach is the use of haptic or acoustic feedback responding to current consumption, or to changes in patterns of consumption.

CONCLUSION

Organizational studies on energy conservation have mainly focused on formal process changes, neglecting the situated energy practices of the office worker. In this paper we showed how this bias can be overcome by using PD approaches and take workers not just as objects of organizational change, but as change agents in the organization. In particular, our study showed that workers do have and do take the responsibility for sustainable energy practices if they get the adequate support. Generalizing these results, we can conclude that even small capital investment can leads carbon footprint of an organization, if we take the potential of changing the situated work into the direction of sustainable energy practices more seriously.

The reflection workshop supported participants to put their personal view in relation to a collective view, creating new insights and discussing new practices using collectively owned electrical equipment. An important issue here was the negotiation and collective interpretation process that happened in the workshop, which leaded to a collective awareness of the use of electrical equipment in the workplace. Such processes create a collective double-loop

learning in the sense of Argyris [1], resulting in a measurable reduction in energy consumption. Here our approach of reflection workshops proved useful in raising latent motivation and potential through the process of alienation and re-appropriation of the own energy practices.

Stressing the social dimension doesn't mean that technology cannot provide valuable contributions. Quite on the contrary, the use of off-the-shelf digital metering technology to record the energy consumption was an important tool to foster the reflection processes. However it was not the installed technology alone what saved the energy. It was the employees who reduced the energy consumption by changing their practices. The novel opportunities of smart metering served as a tool for emancipation, helping users to be aware of their own behavior and the (non-)indented consequences in terms of energy wasting. This means that technology cannot replace the needed social learning process, but the recorded data helps users to underpin their impression with "objective" facts, to identify saving potentials, and becoming a part of energy competence development.

The detailed information on energy consumption in the workplace contributes to a better understanding of the use of electricity. The provided information is a key resource for energy reflection and for the identification of potential savings. However, in order to support the reflection processes, the information must be represented in a way that users can make sense of, and draw connections from it to their own practices using electrical equipment.

Supporting sustainable energy practices at work by making energy consumption more transparent is still at an early stage of development. If we want to make use of new opportunities, we also have to take possible side effects into account. Our study indicated how, making the energy consumption transparent in a workplace context can be an issue that leads to conflicts. Hence, the diverse stakeholders affected by new technology should be included in explorative design research. It is essential for employees to remain owners of their energy consumption information and to be made able to govern the flow of this information, as its interpretation can be very ambiguous and motivate misuse.

In summary we can conclude that there are emerging opportunities to make the energy consumption of workplace transparent with the help of digital measuring technology. Moreover, metering hardware will become cheaper in the coming years, making it ready for the mass market and our research indicates that creating transparency by new technical means and providing feedback systems are not just helpful for the domestic domain [2]. They can also play a very relevant role on supporting energy conservation on the work place.

REFERENCES

1. Argyris, C.: Organizational learning and management information systems. ACM SIGMIS Database 13(2-3), pp. 3-11 (1982).

2. Betz, M., Schwartz, T.: Soziale Dimensionen von Smart Metering am Arbeitsplatz. In: Schumann, M., Kolbe, L.M., Breitner, M.H., and Frerichs, A.(eds.) In: Multikonferenz Wirtschaftsinformatik 2010. pp. 341-352, Universitätsverlag Göttingen, Göttingen (2010).

3. Blevis, E.: Sustainable interaction design: invention & disposal, renewal & reuse. Conference on Human Factors in Computing Systems(2007).

4. Carney, S.: Brecht and critical theory: Dialictics and contemporary Aesthetics. Taylor & Francis 2006, .

5. Chalmers, M.: A Historical View of Context. Computer Supported Cooperative Work 13(3), (2004).

6. Chetty, M., Brush, A.B., Meyers, B.R., Johns, P.: It's not easy being green: understanding home computer power management. In: Proceedings of the 27th international conference on Human factors in computing systems. pp. 1033-1042, ACM, New York, NY (2009).

7. Chetty, M., Tran, D., Grinter, R.E.: Getting to green: understanding resource consumption in the home. In: UbiComp '08: Proceedings of the 10th international conference on Ubiquitous computing. pp. 242-251, ACM, New York, NY, USA (2008).

8. Darby, S.: Making it obvious: designing feedback into energy consumption. In: Proceedings of the 2nd International Conference on Energy Efficiency in Household Appliances and Lighting. pp. 685-696, Springer, Berlin Heidelberg New York (2001).

9. Darby, S.: The effectiveness of feedback on energy consumption. A review for DEFRA of the literature on metering, billing and direct displays., 2006, p. 21.

10. DiSalvo, C., Sengers, P., Brynjarsdóttir, H.: Mapping the landscape of sustainable HCI. In: Proceedings of the 28th international conference on Human factors in computing systems - CHI '10. p. 1975, ACM Press, New York, New York, USA (2010).

11. Ehn, P.: Work-Oriented Design of Computer Artifacts. (1990).

12. Fogg, B.J.: Persuasive Technology: Using Computers to Change What We Think and Do (Morgan Kaufmann Series in Interactive Technologies). (2003).

13. Foth, M., Paulos, E., Satchell, C., Dourish, P.: Pervasive Computing and Environmental Sustainability:. Two Conference Workshops. IEEE, Pervasive Computing 8(1), pp. 78-81 (2009).

14. Hall, A.: Tätigkeiten und berufliche Anforderungen in wissensintensiven Berufen. Studien zum deutschen Innovationssystem, 2007, p. 46.

15. Kant, I.: An Answer to the Question: What is Enlightenment? St. Petersburg (1784).

16. Kelle, U.: Sociological Explanations between Micro and Macro and the Integration of Qualitative and Quantitative Methods. Forum Qualitative Sozialforschung / Forum: Qualitative Social Research 2(1), (2001).

17. Mankoff, J.C., Blevis, E., Borning, A., Friedman, B., Fussell, S.R., Hasbrouck, J., Woodruff, A., Sengers, P.: Environmental sustainability and interaction. Conference on Human Factors in Computing Systems(2007).

18. Murugesan, S.: Harnessing Green IT: Principles and Practices. IT Professional 10(1), pp. 24-33 (2008).

19. Nett, B., Meurer, J., Stevens, G.: Knowledge Management-in-action in an EUD-oriented Software Enterprise BT - Proc of. Knowledge Management In Action (KMIA'08). Springer, (2008).

20. Nett, B., Stevens, G.: Business Ethnography - Aktionsforschung als Beitrag zu einer reflexiven Technikgestaltung (Business Ethnography - Action research as a contribution to a reflective technique development). Institut für Wirtschaftsinformatik, Westfälische Wilhelms-Universität Münster, (2008).

21. Pettersen, I.N., Boks, C.: The ethics in balancing control and freedom when engineering solutions for sustainable behaviour. International Journal of Sustainable Engineering 1(4), pp. 287-297 (2008).

22. Rohde, M.: Integrated Organization and Technology Development (OTD) and the Impact of Socio-Cultural Concepts - A CSCW Perspective., 2007, p. 259.

23. Sellen, A.J., Fogg, A., Aitken, M., Hodges, S., Rother, C., Wood, K.: Do life-logging technologies support memory for the past?: an experimental study using sensecam. Conference on Human Factors in Computing Systems(2007).

24. Siero, F.W., Bakker, A.B., Dekker, G.B., van Den Burg, M.T.: Changing organizational energy consumption behaviour through comparative feedback. Journal of Environmental Psychology 16(3), pp. 235-246 (1996).

25. dena: Hemmnisse für Energieeffizienz in Unternehmen, 2007.