ROLE-BASED ECO-INFO SYSTEMS: AN ORGANIZATIONAL THEORETICAL VIEW OF SUSTAINABLE HCI AT WORK

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Abstract

So far, sustainable HCI has mainly focused on the domestic context, but there is a growing body of work looking at the organizational context. As in the domestic context, these works still rest on psychological theories for behaviour change used for the domestic context. We supplement this view with an organizational theory-informed approach that adopts organizational roles as a key element. We will show how a role-based analysis could be applied to uncover information needs and to give employee's eco-feedback, which is linked to their tasks at hand. We illustrate the approach on a qualitative case study that was part of a broader, on-going action research conducted in a German production company.

Keywords: Sustainable Interaction Design, Information Systems, Organization Theory, Eco-Feedback.

1 Introduction

In recent years, sustainability in terms of energy consumption has become an important issue in preventing environmental pollution. By minimizing energy waste on the basis of more efficient use, a reduction of the carbon footprint should be reached. In the reviews and statistical reports of the European Union (EU), energy consumption is divided into seven sectors (industry, transport, households, service, agriculture, fishing and others) (Keenan and Gikas, 2009).

Seminal work has been carried out supporting people's energy saving in the household sector (Froehlich et al., 2010; Strengers, 2011; Van Dam et al., 2010; Gustafsson and Gyllenswärd, 2005; Pierce et al., 2008; Schwartz et al., 2013a). This work was partially pushed by technological innovations making fine-grained consumption metering in real-time possible (Darby, 2006; Spagnolli et al., 2011). A wide spectrum of domestic eco-feedback design studies explored these new opportunities, reaching from artistic solutions like the Power Aware Cord (Gustafsson and Gyllenswärd, 2005), through pragmatic ones like Watt-Lite (Jönsson et al., 2010), social norm-oriented approaches (Foster et al., 2010; Petkov et al., 2011) to HEMS integrating multiple features into a home-oriented system of services (Schwartz et al., 2013b). Further, several empirical studies demonstrate its effectiveness in not only raising awareness but also empowering consumers to implement savings as well (Darby, 2006; Pierce et al., 2010; Schwartz et al., 2013b; Van Dam et al., 2010). Conceptually, this research is dominated by psychological motivation and persuasion theories (DiSalvo et al., 2010; Froehlich et al., 2010).

Despite the domestic setting, there is growing interest in using eco-feedback at work (Darby, 2006; Pierce et al., 2010; Schwartz et al., 2013a; Van Dam et al., 2010), especially because the industrial sector is responsible for 26% of the total energy consumption (Keenan and Gikas, 2009). In addition, energy becomes an important cost driver so that conservation is not just an ecological demand, but also economically rational (Hirst and Brown, 1990; Worrell et al., 2003). However, compared to the domestic eco-feedback research, the number of studies is quite small. A careful reading further shows that these studies mainly adopt the psychological theories that are well suited for the domestic context.

As noted by Brynjarsdóttir et al. (2012), a sole focus on persuasion is, however, likely to narrow our vision of sustainability. In particular, in the organizational context the isolated focus on motivation might lead to an overestimation of individual factors while underestimating organizational factors.

In this paper, we aim to extend and enrich our view by drawing attention to take both approaches (HCI and IS) into account while designing eco-feedback at work. We show within this paper how both theories can profit from each other. While Organization theory looks more on the organization as a unit with aggregates on people, HCI looks on people itself and their needs. These two approaches complement each other by looking close at the very bottom of an organization (people and their needs) to the very top (the organization as a unit).

2 State of the art

2.1 Eco-feedback at work

In this section, we want to give a brief overview of current research on designing eco-feedback and eco-campaigns in the organizational context. This issue is also linked to the design of Environmental Management Information Systems (EMIS) studied in the topic of IS (El-Gayar and Fritz, 2006; Vom Brocke et al., 2012). This research stream, however, is not further considered as it mainly focuses on the strategic level studying techniques and tools for the green business process management.

Matthies et al. (Kastner and Matthies, 2013; Matthies and Wagner, 2011) conducted one of the studies looking at how ecological information works on the office hallway, by developing checklists, sample templates, etc. to use when conducting eco-campaigns in buildings. With emphasis on companies and enterprises, the German Agency for Energy Efficiency has developed a similar campaign toolbox called MissionE. Both approaches have not been considered smart technologies yet, but mainly focus on media such as posters, flyers, information brochures and letters from superior authorities to motivate employees to save energy by switching off energy consuming devices, turning the heating down etc.

In addition to focusing on traditional media, Azar & Menassa (2012) have investigated into motivational eco-feedback in organizations. In their work, they have developed a framework, which supports the implementation of energy-saving measures in commercial buildings.

An attempt to provide general design guidelines for organizational eco-feedback was made by Foster et al. (2012). Based on a literature review about techniques of intervention appropriate for the workplace, they took the results from environmental psychology (like social comparison, goal setting, etc.) into account (Abrahamse et al., 2007). Yun et al. (2013a, 2013b) implemented a first functional prototype of an energy-dashboard.

In addition, there are some empirical studies evaluating organizational eco-feedback (Carrico and Riemer, 2011), (Murtagh et al., 2013), (Schwartz et al., 2010) with different results. For instance, by providing monthly feedback with motivating messages (Carrico and Riemer, 2011) or installing eco-feedback applications (Murtagh et al., 2013) a reduction of university employees' energy consumption can be reached. But it is also noted that it is a complex relationship between feedback and behaviour and there are many reasons 'not to switch things off'. Schwartz et al. (Schwartz et al., 2010) installed smart metering technology in a research institute and observed that workers take the responsibility for sustainable energy practices if their consumption is made visible and they are supported for example through feedback. That leads to significant positive effects as well, but the conservation fading slowly over time and were not sustainable in the long term.

Currently, we do not have sufficient evidence to make conclusive statements. Yet organizational eco-feedback seems to be a promising candidate for supporting energy saving at work. However, several challenges have still to be solved:

First of all, it seems that one size does not fit all; meaning feedback should be tailored and more action-orientated to reduce the complexity for the users and to enable them to make sense of it (Murtagh et al., 2013), (Schwartz et al., 2010). At first glance, this confirms He et al.'s (2010) seminal critique that one-size eco-feedback is not enough. However, their major argument is that design should consider people's individual stages in a multi-step behavioural change process (Prochaska and Velicer, 1997). In addition to this argument, we provide a further account as to why tailored information is needed due to people having different roles that call for different kinds of eco-information.

Another issue relates to organizational constraints and changing individual behaviour (Carrico and Riemer, 2011) as well as sustaining such changes (Schwartz et al., 2010). These shortcomings are linked to general remarks that simply observing the individual is not enough (Hazas et al., 2012). However, with regard to the organizational context, this statement allows the assumption to be refined and to be made more operational: the alignment of individual changes in combination with organizational changes that influence the behaviour at work (and vice versa) represent a major challenge for organizational eco-feedback design. In other words: how could we support continuous improvement processes by bringing people and processes together, bridging the gap between the operative and the strategic level?

For these reasons, it is generally good advice to consider the specific nature of the context, starting by asking ourselves naively what an organization actually is.

2.2 Organizational Theory-informed Design

At a very general level, organizations are social aggregates that are structured and managed to meet a need or to pursue collective goals. Even if the goals may vary the central aspect of an organization is the coordination of people and resources (Greenwood and Miller, 2010). Organization theory is a macro examination of organizations, because it analyses the whole organization as a unit with difference in their structure on analysis level (Daft, 2012). Managers deliberately structure and coordinate organizational resources to achieve the organization's purpose. They are mainly defined by their internal structure and their inter-relationship with the environment in which they operate (Hernaus et al., 2013).

Applied management research mainly uses such structural views to analyse, manage and design organizations (Hammer, 1990). Here, organizational structure and business processes (sometimes also called operational structure) present key concepts (Hernaus et al., 2013).

The organization structure describes the static nature of organizations, breaking down the whole into smaller, manageable units like departments and sub-departments down to single positions. The organization chart presents a visible representation of the organizational structure with the underlying activities, processes and tasks of departments, units and jobs. The structure depends on the organization's objectives and strategy and is a product of business planning and strategic development. The planning typically covers four elements (Aquinas, 2009):

- The assignment of tasks and responsibilities to define specific jobs.
- Clustering jobs into units and departments to form the organization's hierarchy (departmentalization).
- Defining vertical coordination, such as the span of control.
- Defining horizontal coordination, such as inter-departmental teams.

In general, business processes describe the logical, sequential order of operational events using and transforming diverse resources to the main products or service outputs of a company (Scheer and Nüttgens, 2000). "Resources" refers to any input used during the processes in order to generate output. Resources could therefore be anything from financial (e.g. capital resources), physical (e.g. machinery) and human (e.g. employees and managers) to organizational (e.g. logistic systems). Furthermore, they can be material (e.g. machinery) or immaterial (e.g. energy or information) (Grant, 2002) and can also come from outside the organization or can be produced internally as a product of a sub- or supplementary process. In larger companies, more and more of these resources are planned and managed in integrated enterprise resource systems (ERP) such as SAP (Scheer and Nüttgens, 2000).

Organizational structure and processes are strongly connected but complementary in nature (Hernaus et al., 2013). Moreover, modern planning theories argue that the structure should be reflected and resulted from the deliberate optimization of the processes (Hammer, 1990). Both structure and processes are also of particular interest for organizational eco-feedback as they generally define the person's role together with the power and responsibilities that shape the information needs and the information flows within an organization (Hammer, 1990).

This view is closely related to the Role Based Design as an idea for using business models as a conceptual framework to inform and inspire design (Ferraiolo et al., 2003), (Scheer and Nüttgens, 2000). In addition to ERP systems, another prominent example for Role Based Design is the concept of Role Based Access Control (RBAC) (Ferraiolo et al., 2003). The approach was motivated by the inflexibility of e.g. the access control matrix approach to manage permission in large organizations. The basic idea is not to assign permission to individual users but to roles (e.g. doctor, nurse, etc.). In a second step, users were assigned to these roles in order to gain the privilege necessary to perform his job, but not more. Doing this not only prevents misuse but also safeguards against information overload and feature creep as users gained access to a system tailored to their role and therefore better fitting for the task at hand (Bertok and Kodituwakku, 2002). Moreover, it simplifies administration as role permission can be modified to reflect organizational changes. As a result, a clumsy, time-consuming adjustment of individual permission became obsolete (Osborn et al., 2000).

In the following, we intend to illustrate how a role-based lens could also be applied to uncover the different interests and needs in acquiring eco-feedback within an organization. Such analysis helps to provide tailored information that matches people's capabilities and motivations to save energy either by changing their individual behaviour or work processes.

3 Methodology

The presented study was part of a broader, on-going participatory design action research process (Wulf et al., 2011; Wulf and Rohde, 1995) under collaboration with Alpha, a production company in South Westphalia, Germany. The overall action research mainly follows the traditional action research methodology (Susman and Evered, 1978; Wulf and Rohde, 1995). As part of the diagnosis phase we apply a qualitative case study research methodology to investigate the particular context and generalize the findings to "theoretical propositions" representing our diagnosis about the case (Yin, 2014). In particular, our empirical work aims to understand what the potential benefits, obstacles, needs and opportunities of eco-feedback are, as seen from the perspective of the organization and their practitioner. To gain such understanding, we used common fieldwork methods like participatory observation, document analysis, and interviews (Randall et al., 2007).

The cooperation was enabled by a three-year, publicly funded research project that aimed to improve the energy efficiency of enterprises by using advanced eco-feedback systems. Alpha is not a funded partner, but participated voluntarily due to the project goal being an important goal for them, too.

Alpha operates in the area of fastening technology and has more than 2500 employees in 30 subsidiaries in Europe, North America and Asian. All subsidiaries are part of a holding that is based in Germany. The company's customers are from the automotive and supplier industry, telecommunication and consumer electronics industry as well as from the construction industry.

The company's mission statement includes environmental responsibility and sustainable growth as a key point. Since 1999, the production sites have been certified in accordance with ISO 14001. Furthermore, the standards for conserving resources are reflected when new production centres are being considered. In addition, in 2009 the company initiated an extra project with the goal of handling resources in an environmentally friendly way. The company has a centralized energy management department, which is part of a shared service centre. It is responsible for managing all subsidiaries in this matter. In one subsidiary the company has also started to install smart meters to measure the consumption for most of the machinery.

Our aim was to study the various views of the different internal stakeholders. So, we conduct a stakeholder analysis together with the energy manager. The identification was on the one hand informed by the energy manager knowing the context and our theoretical consideration and on the other hand shaped by general organization research about hierarchical and divisional structure (Orlikowski, 1991), as well as stakeholders mentioned in eco-feedback and EMIS literature (Carrico and Riemer, 2011; El-Gayar and Fritz, 2006). We further used a kind of snowball recruiting method (Biernacki and Waldorf, 1981) by asking at the end of the interviews, which other persons in the organization might find the topic of eco-feedback interesting and interviewing them in turn.

No.	Role	Interviewee
R1	Maintenance	P1, male P2, male P3, male
R2	Controlling	P4, male P5, male P6, female
R3	IT-Department	P7, male
R4	Purchasing	P8, male
R5	Environmentalism, Industrial Safty & Facility Management (EMS)	P9, male P10, male P11, female
R6	Business Division Manager	P12, male (Production) P13, male (Building fasteners) P14, male (Electroplating) P15, male (Engineering) P16, male (Screw) P17, male (Screw) P18, female (Hardening)
R7	Machine Operator	P19, male

Table 1. List of the interviewed persons and their role

With the help of this method we identified a non-exhaustive list covering a wide range of stakeholders. Based on our stakeholder analysis we conducted 19 semi-structured interviews with employees working in different departments and at different hierarchical levels in Germany (see Table 1).

The interview guideline rested on our previous knowledge and research interest, but was adapted in reaction to new insights gained from the interviews. In the end, major guiding questions were:

- What is the role or position in the organization and what is the field of duty;
- For which tasks could information about energy consumption play a role;
- What kind of energy information is useful? Why and how;
- What is your motivation to engage with the topic;

The interviews, which were conducted in the participants' workplaces, were audio-recorded and transcribed verbatim afterwards. The duration of interviews was driven by interviewees, and thus varied in length from 30 to 60 minutes. Our data analysis was based on common button-up coding techniques known in inductive content analysis (Elo et al. 2008). After the interviews, we reviewed and coded the transcripts. At first, we composed categories (such as current energy practices, data needs, energy goals etc.) on the basis of the collected data. Then, we related those categories for our further research.

The following presents the empirical findings first, going on to discuss in detail the lessons learned with regard to designing environmental enterprise systems, taking psychological and organizational factors seriously.

4 Findings

In this section we describe the different views on organizational eco-feedback. Using roles as a structuring element, we outline what are current energy-related practices, the kind of eco-feedback our interviewees considered to be useful and what potential impacts that feedback could have on their practices.

4.1 Maintenance

The maintenance unit is responsible for the functional capability of the machine park and plays a key role in maintaining, optimizing and operating existing facilities. As became apparent during the interviews, the implementation of corrective actions in the area of maintenance is often based on individual employees' specific knowledge and particular experiences with the present machinery.

We observed that in addition to the purchase of technical equipment and systems, the department of maintenance also made great efforts to optimize the energy use of existing machines and plants in the course of their daily work. The maintenance employees mentioned that in regard to energy-related issues, the greatest challenge is a lack of information pertaining to the actual amount of energy consumed, which makes an assessment very difficult. Aiming to understand their local energy system, the employees highlighted the need of an eco-information system offering the possibility of making data visible for maintenance at an operational level. Employees in the area of maintenance expressed the potential and practical usefulness about the actual energy consumption in a way that renders this information helpful for detecting unusual consumption pattern as indicators for the necessity of actions.

> *P2: "in terms of predictive maintenance [...] if the heating element has not 3.1 kW (power) anymore, but only 1.4 kW (power), then I can ask myself: maybe they are completely filthy that I had to make them clean again or (they) go slowly in wear and I have to replace them"*

They also mentioned that in order to supply such provision by energy data, the responsible employee needs a good overview of average consumption patterns in comparison with current energy consumption. Furthermore, they express that scheduling and following maintenance intervals could help when determining the operating hours of a machine based on energy consumption data. Here, for instance, one person suggested integrating the hours of operation into the Enterprise Resource Planning (ERP) system that created notifications at given points in time when a service is due or overdue.

It was also mentioned that, in case of failure, energy data would be helpful in identifying whether it is an electrical problem or maybe a leak at another critical production stage, e.g. the compressed air line due to a significant drop in pressure. Additionally, the system can send a message, which includes information such as meter readings or reactive power (power quality etc.) to support remote diagnosis.

> *P2: In case of machine error: "The colleagues go to the machine and do not even know what causes the problem, but with such system (Energy Information System), they can get much more information before being there like: [...] is it an electrical fault?"*

4.2 Controlling

The controlling department within the company Alpha is divided into central, international and business division controlling. Our interviewees are part of the business division controlling, which deals primarily with the value chain and manufacturing cost controlling. A major goal of the controlling department is the provision of a monthly business assessment for the different business divisions within the company.

At the time of our study, we discovered that the controlling department was using information about energy consumption based on informal communication with the manufacturing and purchasing departments. The controlling department collects this information once a year and takes it into consideration when compiling internal analyses and evaluation.

Firstly, the interviewees emphasized that the interest in energy data was growing increasingly as it became an ever more important cost driver in the production process. Secondly, they mentioned that the current challenges are to break down the energy costs among different business divisions as well as the use of energy information for future price calculations and the product-related estimation of energy costs.

As difficulties in implementing these concepts they express that it is hard to assign the cost of energy to individual business divisions etc. using the existing state of consumption information processing based on total aggregated energy data.

> *P6: "This (more detailed information) would improve all of our operational accounting, for example the direct costs per product that are currently calculated by estimation."*

4.3 IT-Department

The IT-department is responsible for the concern-wide IT strategy of Alpha. The highest priority of the department is to deal with the implementation of industrial data acquisition. Topics concerning energy are therefore less prioritized at the moment. This partially explains why a holistic information management strategy for energy data that covers all aspects of metering, storing, processing and application integration is missing.

On the other hand, however, our interviewee noted that for a comprehensive gathering of production inputs it is also important to consider energy data to provide more information for an operative support of optimizing operations in the manufacturing and production. In addition the energy data can be used to complement the current operation key performance figure systems (e.g. energy costs per produced article etc.).

4.4 Purchasing

The purchasing department is responsible for strategic purchasing and the purchasing of resources. This includes the assessment of the investment decisions of new facilities as well as the purchase itself.

In the field of energy supply, the purchasing department procures electricity and gas for seven subsidiaries and some minor points of consumption. The interview partner mentioned that the current procurement of energy is organized in 10 tranches per year, which are purchased on different timestamps before commencement of delivery.

In order to estimate the required quantities as accurately as possible, the purchasing department is dependent on good energy consumption forecast models. Currently, data is manually captured at a coarse-grained level, which makes an accurate view of the historical consumption very difficult.

From this backdrop, P8 saw the benefit of eco-feedback to obtain timely, fine-grained load profiles of recent years in order to improve current forecast models, even incorporating changes in the machine park. Moreover, for him as the energy purchaser, it is important to have information about the overload and the baseload. Hence, he was interested that eco-feedback systems could help to improve the accuracy of reports on this topic.

Additionally, the purchasing department has a strong interest in energy price forecasting. This would support price negotiations with energy suppliers. For this task it is essential to have a breakdown of the energy costs into the dimensions working price, KWK-apportionment, EEG-apportionment, offshore apportionment and energy tax.

Another request of the interview partner was the eco-feedback-supported assessment of the energy efficiency of the machine park, since there is currently no accurate consumption data that can be attributed to individual machines. As a result, a precise amortization period calculation is impossible. His vision of a future system is to determine the amortization period more precisely due to the calculation of the exact energy demand and the operating hours of the machine. Eco-feedback should actively and reactively inform investment decisions in addition to production efficient calculation.

4.5 EMS Department

The EMS department plays the central role in terms of energy management, which includes the planning, implementation and follow-up tasks. The interviewees divide their tasks into two major objectives. On the one hand, it is about the proof of legal framework conditions that must be met in order to obtain tax refunds, for example. On the other hand is internal and external reporting, which currently includes the following tasks: a quarterly management review, a monthly reporting to the business units, making information available on the intranet, provision of data to the controlling department and creating a table with environmental aspects for the department managers.

Within the legal frameworks, the company has to fulfil statutory requirements in order to gain tax advantages by demonstrating an improvement in energy efficiency. The EMS department therefore defines an internal efficiency target that should be achieved by the organization to meet the legal requirements. In this context, the interviewees expressed it to be essential that the current state be monitored continuously in comparison to the objectives, thus detecting causes for initiating measures as early as possible.

A particularity in terms of legal requirements is the electrical energy that is used for heating. If this consumption is recorded separately, further tax advantages can be claimed. As previously mentioned, the challenge here is to break down energy consumption into the forms of usage (e.g. heat, hydraulic, etc.).

In consideration of the continuous improvement process, an eco-audit is also conducted. Currently, the survey and evaluation process for the execution is done manually, which takes a great deal of effort since a large amount of heterogeneous data is needed.

Within the internal reporting, the interviewees noted that it is currently difficult to provide internal reports to the different business divisions since the granularity of energy data is not fine enough can't be matched to the organizational structure. But to give machine workers and heads of business units data about their influenceable consumption is essential.

> *P9: "They (the workers) mentioned that they can't do something, without data."*
>
> *P10: "Nobody can tell me, what their machine really consumes."*

That makes internal benchmarking on factory basis difficult as well: since energy costs are determined by an allocation formula, the performance indicators cannot be calculated precisely for the specific departments and products.

P10: "We need to know what energy is really needed for a specific product. Not as it is right now [...] then I could imagine that maybe one or more products get pushed out of our product portfolio."

For the department it is particularly important to increase the efficiency in the organization, but to develop measures for energy efficiency improvements, the major energy drivers have to be identified. On the other hand, information about load peaks must be recognizable in the production processes. As an internal reporting tool for efficiency measuring, the company's own key performance indicator (AlphaGreen) is currently used which sets the CO2 emission in relation to the profit and a reference value.

For external reporting and benchmarking across all industries, the interviewees mentioned that standardized reporting should be used in the near future. For this, key performance indicators of the Global Reporting Initiative (GRI) in version 4 should be used to ensure the comparability between companies. In this context, the calculation of a CO2 equivalent should be accomplished as well. Currently, the CO2 equivalent is gaining in importance for supplier evaluation and tenders.

Due to the fact that more and more companies demand the indication of a CO2 footprint from the suppliers, it is important in terms of industry tenders. A CO2 accounting with the calculation of the CO2 footprint should therefore also be implemented by the system.

In summary, the reporting has the highest priority in an energy information system for the EMS department, because the immediate success of the measures can be identified, benchmarking comes into operation and legal circumstances can be proven.

4.6 Heads of Business Units (Production)

The production business area consists of multiple business units, which represent different production stages. In our study, we interviewed the heads of five business units: building fasteners, electroplating, screw, engineering, hardening and the manager of the whole business area.

The production business area manager stated that he does not need special energy management. Production innovations are mainly driven by productivity improvements. Such an improvement, however, will automatically lead to higher energy efficiency. Nevertheless, he acknowledged that his opinion is based on current values calculated by an allocation formula and an exact consumption analysis to prove his presumption is not possible. In his opinion a monthly report should be enough to get an overview if anything went unexpected.

P15: "Yes it (monthly) will be enough [...] to determine whether there tends to be good or bad in terms of [...] energy use, with this indicator we have to deal and should it be deteriorate then we need to search for causes."

Within the building fasteners, the most important energy resource is water, because the water quality has a direct impact on the production process. P13 perceives eco-feedback as useful for the director of the business unit and the sub-region conductors if it provides immediate and operationally useful information (e.g. using a traffic light metaphor when they have exclusive control over a plant, so that situated saving opportunities can be realized).

The electroplating business unit is decentrally managed and so it has several locations. The various locations cultivate an active exchange of energy-related information. Processes and machines are currently compared informally, so the challenge mentioned by P14 is to support this by sharing real consumption data of the plants and providing features to enable best practices to be shared.

The head of electroplating was further interested in calculating the energy costs that reflect the cost centre structure of Alpha. He was also interested in obtaining feedback about unusual behaviour or consumption levels (especially compressed air) so that necessary action can be taken quickly.

The business unit screw currently sees only a very small potential for saving energy. However, the interviewees noted that for a closer look at consumption optimization, they first need precise energy data to analyse the current processes within the department.

The hardening department is one of the most energy-intensive units of the whole organization. It has a high utilization of production capacity and strict specifications in energy use (exact heat on the basis of different chemicals). P18 assesses the saving potential as very limited. This also reduces her interest in and demands on obtaining more detailed eco-feedback. However, she did see the benefits of using the data to support investment decisions due to better return-on-investment (ROI) calculations.

Also, the engineering department thinks that eco-feedback would only help them marginally to act in a more sustainable way. However, intelligent analyses of consumption patterns were of interest to them; in particular in order to investigate if it is worthwhile to shut down machines when they are not in use or if the setting-up exceeds the saving effect.

> *P15: "I want to know about wastage, for example times of standby that are not allocated directly to a product."*

4.7 Machine Operator

The machine operators are responsible for the operation of the various production machines and are thus directly integrated into the production processes. In the interview it became clear that a large amount of informal knowledge in dealing with the machinery has become available through their daily work.

When employees discuss their experiences and best practices among themselves, energy is a common theme, but mostly at an abstract level since no accurate consumption data exists. P19 did, however, mention that real energy consumption data would be interesting for him so that he could explore how much energy individual procedures require.

5 Discussion

So far, the design of eco-information is mainly studied in the domestic context. Therefore, we want to discuss the lessons learned with regard to common topics, but also to seminal differences. Because of the differences it could have a negative impact to just apply the design concepts from the domestic context (Carrico and Riemer, 2011; Foster et al., 2012; Froehlich et al., 2010) or at least not fully develop it's potentials.

Comparing the domestic and organizational context

As in the domestic context (Froehlich et al., 2010; Schwartz et al., 2014, 2013b), our study shows that consumption data itself does not save energy, but must be contextualized before it became useful. Concerning this, organizational eco-feedback design will benefit from existing research, improving people's sense making of energy data (Schwartz et al., 2013a, 2013b). Additionally, like in the domestic context our study reveals not only to obtain absolute feedback, but getting relative feedback with regard to what is "normal". However, the devil here is in the detail. While the request seems to be general, the individual definition of people about what is "normal" seems to be highly context dependent (Strengers, 2011). Hence, we should investigate in context-dependent key performance indicators (Scheer and Nüttgens, 2000) for "normality" as well as providing feedback mechanisms that allow users to define their own concept of "normality" (Schwartz et al., 2013b).

Another important difference between both contexts is the motivation of the people. In the home context, people are mostly motivated by ecological or personal economic benefits. In contrast, our interviewee mentioned that better energy-related information would help them to improve their work and increase the efficiency of the organization. This is related to the different needs concerning tailored information (He et al., 2010; Abrahamse et al. 2007). In both contexts, the statement of He et al. that one size does not fit all is true. However, in the domestic setting the tailoring is mainly resulted by individual-psychological factors (e.g. because people are in a different stage of a multi-step behavioural change process: He et al., 2010). In contrast, in companies the needs and motivations of people are much more shaped by the organizational structure (see also Table 2 for a survey of the information request). So in addition to individual-psychological factors, the information in organization must be tailored because of and with regard to the different roles and tasks.

Related to this, the situation within an organization can be characterized as different views on the same data stock. So instead of having a design isolated solution for each person, we should provide a kind of a central Eco-Data Warehouse, where the information is tailored at the logic and presentation layer (Scheer and Nüttgens, 2000).

Another important difference to the home context deals with the IT-landscape in organizations. Compared to the home context they are often quite complex, so it is not useful when eco-design merely add another detached application. Instead, the eco-information should be seamlessly linked and integrated into the existing applications in order to provide meaningful information within people's ordinary work context.

Role	Task	Information Request
Maintenance	Ensure that the operational state is maintained (preventive maintenance) or to restore failures.	• Trajectories of fine-grained energy consumption data for the detection of unusual consumption patterns • Machine operating hours based on energy consumption • Real-time information (e.g., meter readings, power quality) for error identification and error forecasts
Controlling	Systematic recording, monitoring and informational compression of data for report and cost allocation.	• Energy consumption per produced output (direct cost allocation) • Energy consumption by cost centres • Energy driver + peaks
IT-Department	Oversight of all information technology equipment, configuring network access, setting up and making changes to existing workstations and assigning access rights at various levels.	• Timely gathering of consumption for integration in operational data collection
Purchasing	Supplying the company with goods and services that are required but which could not be produced by the company itself in order to carry out the production process as well as the planning and controlling of material cost development.	• Representation of the energy consumption compared to the acquired tranches • Tranche-based and monthly-based forecasts of energy consumption
EMS	In addition to the tasks on occupational safety and facility management, the major tasks consist of the observance of official environmental concerns and ensure a sustainable environmental impact of company products and processes and the behaviour of its employees and stakeholders.	• Timely energy consumption for reporting issues • Fine-grained data at location level, business unit level, organizational unit level and hierarchical level • Consumption by use (heat, mechanical etc.)
Business Division Manager	Planning and monitoring of the department to ensure that the strategic plans of the management are implemented.	• Energy consumption of the business division • Energy consumption at machine level linked with machine operating times for investment decision • Information about the energy consumption from a machine with different states (e.g. hardening machine with different temperature settings)
Machine Operator	Responsible for the operation of the production machinery.	• Real-time data for identifying optimization potential • Sharing expertise using machines more efficient and knowledge about saving potentials

Table 2. Summary of the various roles, their task and their environmental information requirements

Implication for Design

In order to benefit from the research in IS and HCI, the design of Environmental Management Information Systems (EMIS) should take both the commonalities as well as the differences between both contexts into account. Concerning this, we argue for a two-step design approach where information tailored at both organizational and individual level: On the organizational level, the tailoring should first consider the horizontal and vertical dimension. As a rule of thumb on the operational level, information should be tailored to be action oriented, while on the strategic level it should be a more planning oriented. Next to this, we should closer investigate the functional role, the tasks and the particular work context. For the final polishing we should take personal preferences and individual-psychological factors into account.

In the following we outline this issues in more detail.

Interactive, analytic tools at strategic level
Managers typically had a long-term oriented perspective on energy consumption. They do not therefore ask for real-time feedback, but for strategic decision support that makes use of the fine-grained data pertaining to organizational consumption. Here, interactive tools for reporting what is going on in subordinate divisions, forecasting consumption and scenario-simulations seem to be more suited. Also, getting information about costs was a common demand. EMIS should further breakdown strategic objectives into operational objectives, so that the level of achievement can later be reflected back.

In regard to benchmarking: standardized (external) reporting plays a crucial role. They allow the use of known practices for reporting environmental information and the comparison with other companies. In addition to such standard reports, tools for internal reporting are needed as well. As said, what is normal is highly contextualized. Our study reveals that managers want to supplement standards by own KPIs to better reflect the special context of the organization.

Simple, direct eco-feedback at operational level
At operational level, our study reveals that feedback is needed that helps people on the shop floor to save energy directly and in situ. Current approaches in HCI address this demand by using the concept of direct feedback (Darby, 2006; Froehlich et al., 2010). Here, the highest priority is to give simple information that can be interpreted immediately.

In the work context this general demand of simplicity have a high priority. For instance, we observe that a worker gets some basic information about the current state of a machine. This information should only be enhanced by the most important eco-feedback for this particular situation in order to prevent both information overload and a distraction from work. So symbols like a traffic light and/or easy-to-understand numbers seem to be best suited here. Nevertheless, also common eco-feedback design techniques (Foster et al., 2012; Froehlich et al., 2010) such as using additional graphs, text, or symbols should be used, if it helps to make the information easy to grasp. Additionally, the visualization should contain supporting elements, such as alarm functions that attract attention if action is nec-

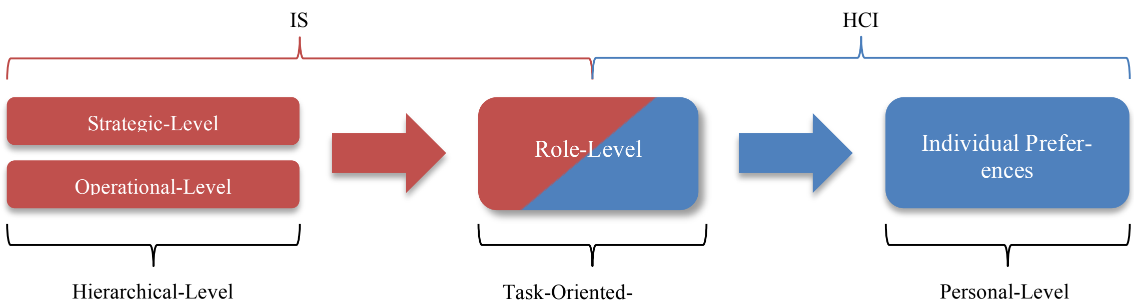

Figure 1. Using IS research in HCI for designing eco-feedback at work

essary. In contrast, more complex information should only be visualized on request.

At the operational level cost calculations and money-based feedback seem not that important as it is on the strategic level. One reason might be that planning costs was not in the responsibility of the people and there was no direct personal economic benefit by saving energy. So instead of getting economic feedback, people were interested in energy informations that help to increase there work effectiveness. This shows that we should reduce the design of EMIS on the operational level, not just on motivating workers to behave pro-environmentally (Carrico and Riemer, 2011; Foster et al., 2012), but first of all to analyse what value such information could have for them to improve their work.

Roles for task-oriented visualization

Within this binary division, process and role model descriptions of a company help to customize role-based eco-feedback. Especially, the role's sphere of influence is very important, to provide only information that can be influenced by the users.

> *P10: "The people always say to me that they don't want key performance indicators that they cannot influence"*

Additionally, the process and role model description can give further insides into the working context, the used information systems and the used machines of the users to enrich energy-data to better fit in daily practices.

In the extreme, such role-based tailoring leads to each role in the company having their own view. It is, however, much more compact for each role to have their own view than for each person (Ferraiolo et al., 2003), this is also true for the administrative costs of such a system in practice.

Individual Level

Here at the individual level, the final polishing of design benefits from proved eco-design strategies like gamification, goal setting, persuasion, etc. to improve the individual motivation to save energy (Froehlich et al. 2010, Abrahamse et al. 2007). In addition, designs should provide tools to support common sense-making strategies of people making consumption accountable, e.g. by comparing devices, people or routines (Schwartz et al. 2013). In addition, the system should not just provide tailored information, but provide means so that users could tailor them to their personal preferences and the local context (Lieberman et al., 2006). In this respect, we see a high potential for HCI to contribute to current EMIS research (El-Gayar and Fritz, 2006) to make this systems more usable and persuasive.

6 Conclusion

We contribute to eco-feedback research by supplementing the common psychological, persuasion-oriented lens (Carrico and Riemer, 2011; Foster et al., 2012; Froehlich et al., 2010) by an organizational, role-oriented lens (Aquinas, 2009; Ferraiolo et al., 2003; Scheer and Nüttgens, 2000). Using lenses helped us to uncover the different views on organizational consumption within the company, especially motivations and needs that go beyond "save-the-earth". Such analysis informs us how to outline a role-based design approach that prevents the one-size-fits-all shortcomings (He et al., 2010). We further outlined a realization concept relying on the common software-architecture pattern providing a central database with various views (Scheer and Nüttgens, 2000).

We have further argued that these views should be tailorable at two levels: At the organizational level, eco-feedback should be adapted to the hierarchy level and the diverse roles in the organization. At the individual level, it should be modified to personal preference and situated needs.

Our study further reveals that we should distinguish between operational, direct feedback supporting short-term savings and strategic, analytic feedback supporting long-term savings. Most approaches today focus just on the first, but neglect the latter. This has partially resulted from the psychological lens. However, we view the psychological and organizational lenses as not being mutually exclusive, but as supplementing each other in order to enlarge our design visions in sustainable HCI (Brynjarsdottir et al., 2012).

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