The Missing Link: Connecting Building Technology to Social-Psychology

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Abstract

Current building and system control strategies make use of the rule-based automation of technical components to control indoor environmental conditions and energy use. The event of a building occupant interacting with the environment is considered as an error to be resolved by the system. The limited opportunities for the user to interact with a system controlled indoor environment results in users dissatisfaction. That leads to the adoption of behavioral pattern to trick the system, which results in an non-optimal energy use.

To exploit the energy saving potential of the existing building stock, the user-specific requirements need to be considered, differentiated and integrated to the building and system control strategies. What is needed is a user-centric approach for building and system controls which includes communicating the current state of the system to the user. The authors argue that it needs a strong integration of social-sciences and technology to integrate the building user and building technology.

This contribution presents preliminary research results to identify the use-related energy saving potential in Swiss buildings and expert feedback to a prototypical interface between user and building technology.

Author Keywords
Energy saving potential, building technology, social psychological intervention models, building technology, building performance, internet of things

ACM Classification Keywords
Human Factors, Management, Performance

Introduction
The estimated saving potential of the Swiss building stocks final energy demand is with 29%, corresponding to 16.5TWh, extensive. The challenge lies in exploiting this potential whilst maintaining a comfortable and healthy indoor built environment. Currently, purely technology focused strategies consider the user as a source for errors, purposely excluding the building users and their needs [EN15232 2007].

The authors argue that, on one hand, purely technology driven strategies such as building automation and predictive system controls are not able to resolve the problems related to occupants dissatisfaction but can contribute to an non-optimal energy-use.

On the other hand, strategies which focus on the provision of information to the user, e.g., smart metering fall short to achieve substantial energy savings due to observed phenomena such as habituation and rebound effect.

The questions that have been addressed in this contribution are:

- What is the use-related saving potential in Switzerland?
- Which communication and psychology related models need to be addressed in order to reach the building user?
- Which functionality is required for an interface between user and technology to communicate building and system performance data to avoid observed phenomena such as rebound-effect and habituation?

Methodology
Four research methods were applied to answer the posed research questions: (1) literature surveys, (2) expert interviews, (3) prototyping and (4) user testing.

A *literature survey* was conducted on a number of selected subjects , e.g., building specific energy use, user behavior, performance prediction, social-psychological models and user intervention.

Expert interviews: In order to quantify the user specific energy demand for Swiss buildings, four building types where selected: hotels, schools, office buildings and shopping centres. For those building types user groups were differentiated and expert ,representing the important user-groups, interviewed.

Prototyping . The building type school was selected for developing a prototypical interface to provide the user with instantaneous feedback to his/her interaction with selected building system components and indoor environmental conditions.

The prototype was developed iteratively with user-testing as final step in each of the three iterations. For the user-tests online questionnaires were developed. The number of expert users present during the prototype testing varied between 4 and 6.

Use-related energy saving potential

To establish the use related saving potential two different types of data sources and inherent uncertainties were combined using a Monte Carlo simulation with Latin hypercube sampling. The data sources were: (1) documented energy use data and (2) expert feedback to an semi-structured interview on use-related energy saving potential. Figure 1 shows exemplary the use-related saving potential for final electric energy demand. It can be noticed that shopping centres have the highest and schools the lowest saving potential. As the data obtained for schools is characterized by a reduced uncertainty and moderate probability, a prototype was developed for a class room in a local school building.

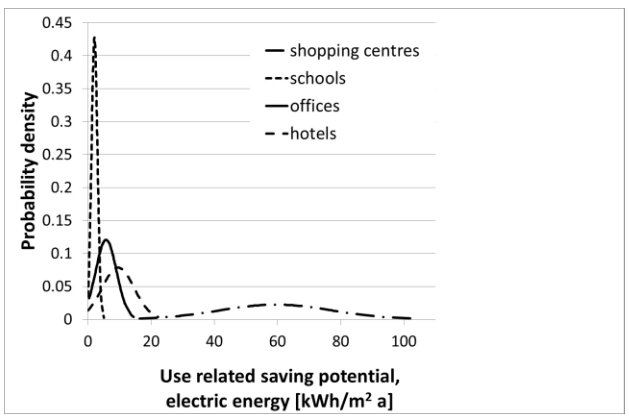

Figure 1: Use-related electric energy saving potential for four building types in Switzerland: shopping centres, schools, offices and hotels

User-centric communication of building & system performance data

The available body of knowledge to communicate data to a consumer is extensive and used in many industries successfully. However, the application of that knowledge to the domain of building technology has not yet been recognized as an interdisciplinary research field.

Data-Information-Knowledge conversion model

Many of the discouraging results to achieve lasting energy savings by installing smart-meters can be attributed to the fact that data alone is no basis for a directed decision.

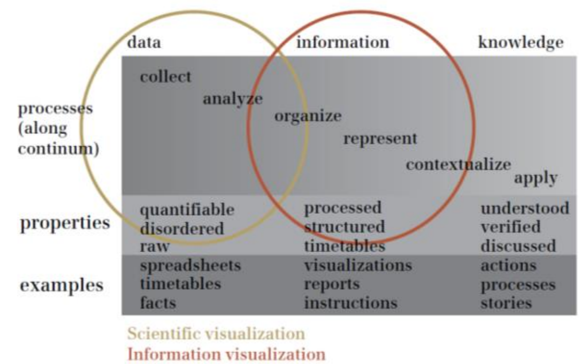

Figure 2: DIK-model differentiating the scientific and and information visualization domain, adapted from [Judelman 2004]

Following Judelman [2004], see Figure 2, data needs to be analyzed and organized to become knowledge and be representative and contextual to become knowledge to be acted upon.

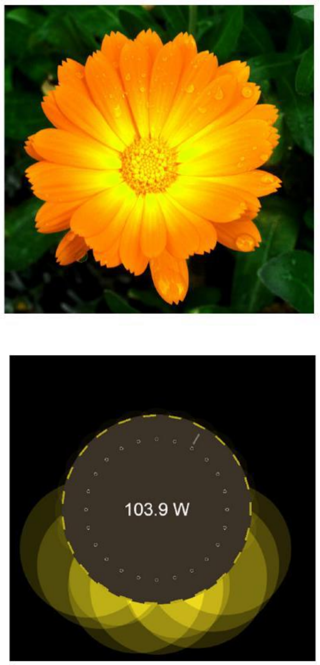

Figure 4: Visualization concept for energy use and indoor environmental conditions , adapted from Ubuntu mobile welcome screen

User-intervention

The recognition of the impact of building occupants on building energy consumption has led to an increase of research activities into techniques for user intervention. The focus of the reported efforts is on the formulation of intervention strategies and long-term maintenance of behavioral change. A common socio-physiological base has been provided by Ölander and Folke [1995] with the formulation of the Motivation-Opportunity-Ability Model. Artho et al. [2012] extended the model in 2012 including the factor perception, see Figure 3.

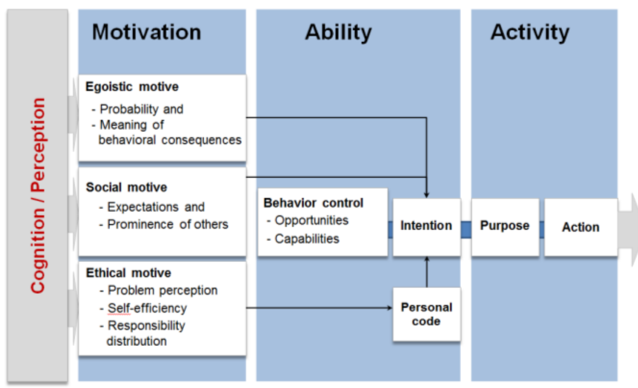

Figure 3: Adapted Motivation-Opportunity-Ability Model [Artho, Jenny and Karlegger 2012]

Information perception

The recognized limits for studies on user intervention are: the focus on voluntary behavioral change excluding structural factors such as technological development, economic growth, demographic factors, institutional factors and cultural developments also termed TEDIC-factors [Wilson and Hawkins 2011].

Other aspects which have been observed are: limited reporting of the dynamicity of the user influence and the missing possibility for interacting with the reported data [Struck et al. 2011; Struck et al. 2012]. Based on a literature survey the following criteria for evaluating performance visualization concepts have been formulated:

- Enabling the user to influence parameters: Opportunities for the user to interact with the parameter – creating a sphere of influence.
- Preventing sensory habituation: Opportunities for the user to interact with the data visualization to prevent sensory habituation.
- Contextualization: Extent to which data is contextualized with respect to space and room use.
- Intuitive readability: use of intuitive data presentation formats with regards to human data processing capacity.
- Artistic intervention: The potential of the data visualization format to allow artistic manipulation.

Prototype development and testing

Three prototypes were developed and tested. The aim was to successively integrate and facilitate functions for sensoring, data store and communication with the building user.

Third prototype

All prototypes resembled data networks plus visualization concepts to communicate energy use, relative humidity and CO_2 concentration. The chosen visualization concept integrated projectors and Kinect®

Figure 5: Impressions of the projected visuals during the user-testing of the third prototype

cameras to interact with the projection by touch on the wall or other activated objects.

A schematic of the third prototype is shown in Figure 6. The following functional requirements were defined for the third prototype:

- enable user interaction with environmental parameter and energy use;
- enable user interaction with the data presentation format;
- integrate the data presentation format into the architectural room concept.

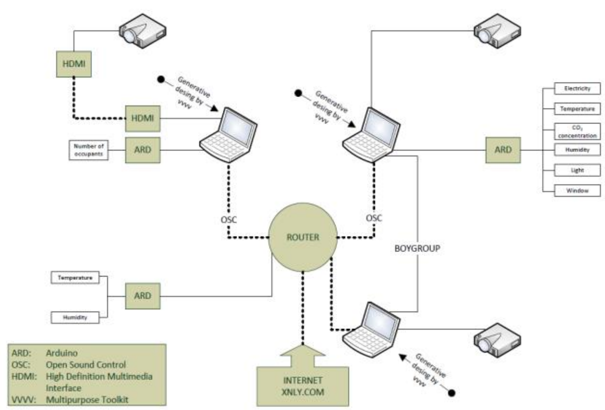

Figure 6: Schematic of third prototype for user-testing

User testing

Practitioner guides to user testing suggest applying usability engineering techniques throughout the product design process from high-level to detailed design [Dumas and Redish 1999]. The developer is tasked to:

- focus early and continuously on the user;
- consider all perspectives to usability;
- test versions of the product with users early and continuously;
- iterate the design according to the feedback.

The participating expert users were to follow a demonstration of the prototype functionality before testing the prototype themselves. After testing they were asked to fill in an online questionnaire.

It was found that the experts assessed their impact on the energy demand higher than their impact on the indoor environmental quality. Furthermore, experts concluded that being able to interact with the presentation format to ease the acceptance of the communication medium.

Two questions were related to the aspect of using historic trend data for supporting intervention measures or projected (future) trend data in combination with real-time data. Although the mean of the scores to both questions over the six participant's is not significantly different the deviation varied significantly, indicating disagreement.

Summary

The focus of current building and system control strategies on rule-based automation of technical components only reduces the potential to sufficiently exploit the anticipated energy saving. The estimated use-related savings for the four building types vary between 2 and 60kWh/m^{2}a.

Current smart-metering initiatives do not achieve a lasting energy saving as they ignore the need to convert data to knowledge. To provide a basis for user intervention performance data needs to be contextualized and interactively communicated to allows intuitive readability.

Socio-psychological activity models are continuously being extended to better describe the interaction of the humans and their environment. Intervention studies, in a particular, represent one driving force.

The developed and tested prototypes give a good indication that currently available technologies provide a sufficient foundation to allow for the user to successfully and quantitatively experience the consequences of his/her interaction with the indoor environment technological system components.

References

1. ARTHO, J., JENNY, A. AND KARLEGGER, A. 2012. Themenbereich Haushalte - Forschungsprojekt FP-1.4. In Wissenschaftsbeitrag Universität Zürich, Sozialforschungsstelle, Zürich, 225.
2. DUMAS, J.S. AND REDISH, J.C. 1999. A Practical Guide To Usability Testing Intellect Books, Exeter.
3. EN15232 2007. Energieeffizienz von Gebäuden – Einfluss von Gebäudeautomation und Gebäudemanagement.
4. JUDELMAN, B. 2004. Knowledge Visualization - Problems and Principles for Mapping the Knowledge Space. In International School of Media University of Lübeck, Germany, 175.
5. STRUCK, C., BOSSART, R., MENTI, U.-P., AEBERSOLD, R. AND STEIMER, M. 2011. Towards more effective communication of integrated system performance data. In Proceedings of the CISBAT 2011, Cleantech for sustainable buildings, Lausanne, Switzerland, 14-16 September 2011 Solar Energy and Building Physics Lab (LESO-PB).
6. STRUCK, C., BOSSART, R., MENTI, U.-P. AND STEIMER, M. 2012. User-centric and contextualized communication of integrated system performance data. In BauSim 2012 Gebäudesimulation auf den Größenskalen Bauteil, Raum, Gebäude, Stadt, Stadtquartier, C. NYTSCH-GEUSEN Ed. IBPSA, Universität der Künste Berlin, Germany, 6.
7. WILSON, T. AND HAWKINS, L. 2011. CCBRP WORKING PAPER - Changing household energy behaviours: key findings from a review of applied research The Scottish Government, Edinburgh, 14.
8. ÖLANDER, F. AND THØGERSEN, J. 1995. Understanding of consumer behaviour as a prerequisite for environmental protection. Journal of Consumer Policy 18, 345-385.