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Resource Efficiency in Buildings through Automation and User Integration (REGENA[1])

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Abstract

The aim of the REGENA research project is the conceptual development and the comparative evaluation of low-investment measures for optimising building operation energetically in universities and colleges. Besides an analysis of building technology, emphasis is also placed on environmental psychological consideration of user behaviour. Using a comprehensive monitoring system, the energy consumption of the two participating universities is to be monitored. Additionally, intervention measures to reduce the energy consumption will be organised and evaluated. As a result, a transferable process model (REGENA-Model) will be developed, which will be generally applicable to universities.

1. Introduction

Recent observation of energy consumption distribution shows that public and residential buildings consume **40%** of the whole energy consumption in the European Union (EU). Public buildings consume **37 %** of this energy (Wicaksono et al. 2010). Universities belong to public buildings and their share of the consumed energy is non-negligible. Therefore, an efficient use of energy resources in universities would firstly be compatible with Kyoto Protocol to lower CO_2 emissions and secondly reduce the EU energy import dependency. Regardless of this, the evidence of still rising energy requirements (lighting and HVAC: Heating, ventilation and air-conditioning) and energy prices forces universities, as well as other institutions, to consume energy more efficiently.

To reach these objectives, and furthermore to achieve or maintain their position as model in environmental issues, more and more universities in Germany have introduced energy management systems (EnMS[5]) to monitor and control their energy consumption (Liers/Person 2012). Others (e.g. the Universities of Freiburg, Göttingen and at the Free University of Berlin, ibid.) have integrated psychological intervention to guide user's behaviour towards more energy efficiency, which we will call "psychological intervention for green user behaviour" (PIGB). Applied separately as well as together, the effectiveness of the two instruments is proven: the EnergyAgency NRW (North Rhine-Westphalia) estimates that up to 15% higher energy efficiency is possible by PIGB (Otto-von-Guericke-Universität Magdeburg, Institut für Psychologie I). This does not mean that these instruments are free of disadvantages or weak points.

[1] REGENA (Ressourceneffizienz im Gebäudebetrieb durch Nutzerintegration und Automation) German translation of the title

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[5] Besides buildings service management, EnMS also includes building automation system.

EnMS are often very expensive and, unfortunately quickly reach a saturation point regarding their impact on energy consumption PIGB have to be applied very sensitively, since they affect humans. Therefore, any bad application could have high rebound effects. In addition, they must be applied continuously, since the concerned persons frequently change (especially in universities, each semester new students and new staff are involved).

Regarding all these facts, our main research question is: How can PIGB and EnMS be improved by means of environmental informatics, balanced and interlocked to provide a relevant increase in energy efficiency of buildings under various initial conditions, especially in university buildings?

2. The REGENA Project

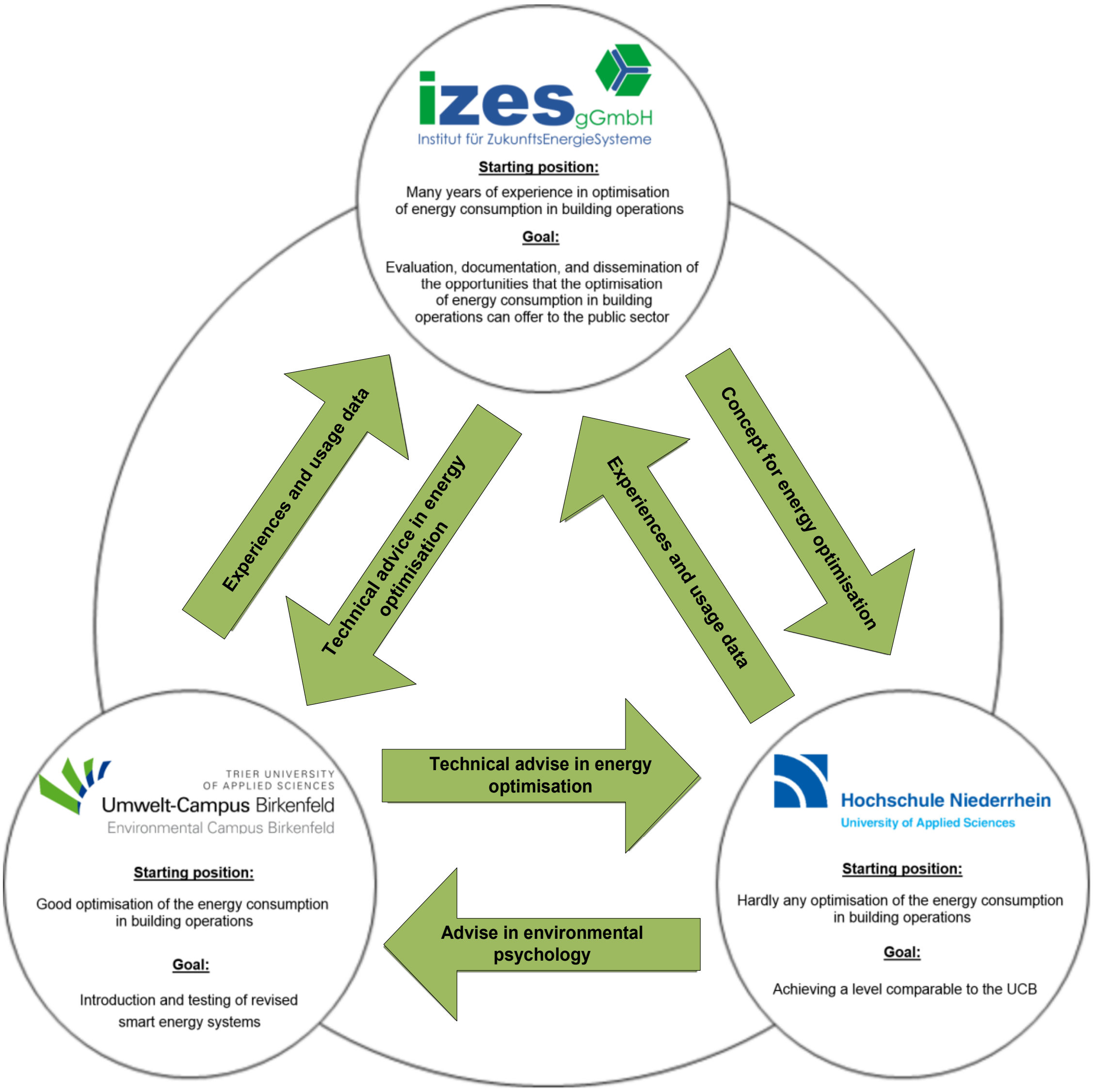

Figure 1
Project partners and their cooperation

The aim of the REGENA research project is the conceptual development and the comparative evaluation of low-investment measures for optimising building operations energetically in universities and colleges but also in public buildings. In contrast to many other project ideas, the REGENA project is not limited exclusively to the "user behaviour" or "technical measures" as independent optimisations to save energy. Instead, it is investigated how the instruments "user behaviour" and "technology" can be linked together to develop appropriate methods and tools to improve the energy consumption in building operations. The project partners are the Trier University of Applied Sciences / Environmental Campus Birkenfeld (UCB), the "A.U.G.E-Institut" of the University of Applied Sciences Niederrhein (HS NR) and the "Institut für ZukunftsEnergiesysteme" (IZES) in Saarbrücken. Due to the technical experience of the UCB and the environmental psychology background of the HS NR, this is an ideal starting position to exchange know-how in technical areas, as well as in psychological fields, between the two universities and to accompany and spread the results by an independent institute (IZES) (*see figure 1*).

Based on a detailed analysis with the two universities (UCB and HS NR) as test sites regarding their present automation system, their EnMS, and how they are used, we will, in addition to our main research question, examine the different aspects of the following scientific sub-questions:

1. Aspect of data acquisition, visualisation and analysis, and EnMS:
    - Which supervisory control and data acquisition (SCADA) of energy consumption is meaningful?
    - How should SCADA be organised and implemented, so that it increases the energy efficiency and is suitable for all users?
    - Which data analyses are possible and make sense? What are reasonable evaluation methods and tools?
    - Which EnMS are required for a resource-efficient university building management system?
    - At which level of automation can PIGB be used to complement EnMS?
2. User aspect:
    - Which user groups are present at universities and how can they be integrated in the energy control loop?
    - In which cases is PIGB reasonable, welcome, or counterproductive?
    - How can a sustainable motivation of users be reached?
    - What are the interactions between EnMS and PIGB?
    - Which visualisations of energy consumption are efficient and user-oriented?

Referring to the solutions of all these scientific issues, we intend to develop a transferable model, the REGENA-Model, whose strategies and methods allow energy optimisation at universities with small financial investment. The REGENA-Model carefully considers all administrative, technical, and particularly information technology specific issues at universities. Therefore, prior to stating our approach to the REGENA-Model, we provide a short introduction describing the major problems we faced until now:

Due to the facts that most of the universities have new and old (sometimes renovated) buildings, and that they are under heterogenic use, universities are subject to diverse technologies. For example we found

various data-transfer systems such as European installations bus (KNX/EIB), Meter Bus (M-Bus), Local operating Network (LON), etc. Unfortunately, these communication systems are not compatible and even in the rare cases that they are, they do not work together easily. Therefore, we require ontologies that are able to expose those diverging data-transfer systems as one single, technology neutral, data transfer system. Ontologies are usually created manually, by experts, and therefore very time consuming (Wicaksono et al. 2010). Independent of the data transfer system all data has to be saved in a database installed on a server. These servers, whether they are virtualised or not, are maintained by the university electronic data processing centre (EDPC). Furthermore, the EDPC is responsible for all desktop PCs in the university (hard- and software). To maintain all those systems, it is necessary to execute a periodical recovery of the servers. This recovery process leads to data gaps in the databases on our measurement servers (among others).
As mentioned above, we will consider and propose solutions in our REGENA-Model to fix these and other problems.

3. Steps to the REGENA-Model:

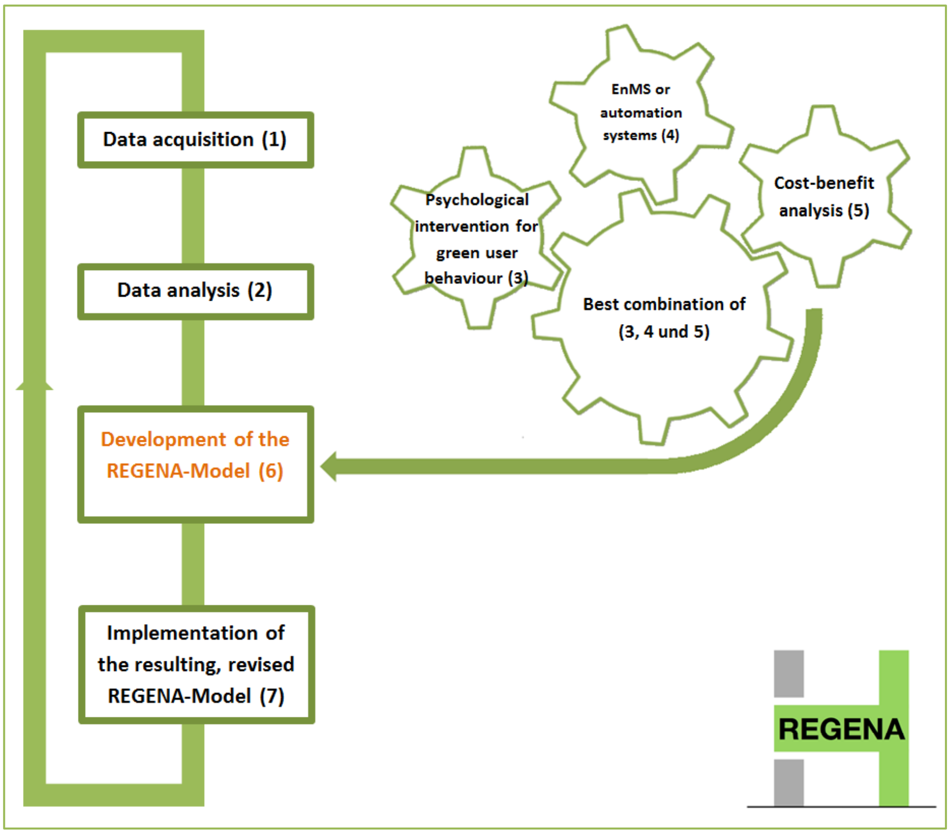

Figure 2
Monitoring

To achieve our goal, we are about to implement a monitoring system that will systematically and continuously collect energy data and analyse it. The REGENA-Model will be created as shown in the figure 2.

(1) Data Record: We collect and record all types of energy data (Heating, Ventilation, and Electricity). To involve diverse types of users, we selected various room types to observe: For example at the Environmental Campus Birkenfeld we distinguish three different room types. At first we look at three lecture halls and one seminar room, where we will primarily work with students but also professors. Secondly, twenty eight employee’s and professor’s offices and two meeting rooms are examined. Finally, we take measurements at a technical laboratory.

For all heat measurements, we have decided to use heat cost allocators, because it is proven that a consumption-related measurement can help the user to reduce his consumption by 15 to 20% (Fantl 1978 cited in Adunka 2011). In addition, heat cost allocators are the cheapest method.

For electrical measurements in offices, we distinguish between lights, electronic data processing (EDP) power sockets, and normal power sockets. So we will be able to get measurement results for the different sources of consumption and react suitably. Regarding lights, we plan to implement or improve a day-dependent lighting system and observe its influence on the energy consumption. We also intend to make separate measurements for ventilation (warm and cool) if it is possible.

(2) Data Analysis: We intend to record data in a database. Aided by a semi-automatic analysis tool, we will make a refined research to detect all unusual values, their origin, and their dependence to PIGB or to EnMS.

In order to record data, we have to **transfer** it to a **server** and here we face the above-mentioned problem of diverse data transfer technologies and the problem of frequent backup and recovery operations. There are many data transfer technologies at our test sites at the UCB. The installed energy consumption meters are primarily connected to KNX/EIB and to M-Bus, the rest uses radio or TCP/IP with the FTP protocol. Although the data coming from KNX/EIB and M-Bus are viewable from a single energy management software, both systems are physically separated from each other and the data is not accessible in real time. Therefore, a parallel real time data access monitoring system that will not disable the existing one is required for the project. Merging both systems, either by hardware or by software, will solve this problem, we have chosen the second possibility.

(3) PIGB: Psychological interventions will mainly take place in form of user trainings. To monitor user motivation and the success of the trainings, we developed questionnaires for user behaviour, which are based on the structure model of Homburg (Homburg/Mathies 1998) and the norm-activation model of Schwartz (Schwartz 1977). The questionnaires are divided into two parts: a so-called frame condition part (technical conditions of various room types, e.g. lecture halls and offices) and a part on the attitude of users (knowledge and personal standards). The baseline surveys will take place prior to the first user trainings. Subsequently, the inquiries will be repeated, in order to discover changes in user attitudes.

The trainings will be complemented by positive prompts, e.g. information signs, stickers, notes on screen, etc., to support new energy-saving behaviours. An example prompt might state: “Remember to turn off this screen, the lights, and the printer” (*see step 4, figure 3*). Such positive prompts are more effective than interdictory ones and strict instructions (Bell et al. 1996/Durdan et al. 1985 cited in Mack 2007).

Another psychological intervention that we will use is feedback. This method offers the user an option for monitoring her/his long-term energy-saving behaviour. By using comparative feedback, users have the option to compare their own energy consumption to the average consumption (*see step 4, figure 3*).

(4) EnMS or automation systems: All common automation systems that go hand in hand with PIGB, and whose prices are relatively low, will be tested to see how far they can be used in our REGENA-Model. The two most important features of EnMS that go together with PIGB are the possibilities of virtual metering and the feedback possibility.

Virtual metering is a possibility offered by decentralised systems as LON or KNX/EIB, because the status of each element in the circuits is known. The energy consumption of all lights in a room can be determined without any measure instruments knowing the status of the light actuators in this room and the power of the lamps. This is also possible for electrical blinds. However, it must be said that this method is not precise, due to status transmission time to the software and due to the irregular power especially at the ignition.

Feedback is common in EnMS, for example sending a text message or e-mail to the staff of the building control when a visualised value (for example the temperature in a server room) exceeds a critical value. Normally, there is a limited number of persons to whom text message and e-mail can be sent. According to our feedback policy, we want to make this number unlimited, so that any user of a room in universities or public buildings can frequently receive e-mails or text message with information on her/his own light energy consumption and other important information. E-mails and text messages are not the only ways to give feedback to users. We will implement windows system messages that frequently appear at the right bottom corner of user's screen. Other feedback possibilities are also windows system messages at logoff, logon and when turning off the computer (*see Figure 3*). We intend to change the design of all feedback possibilities to make them always appealing to read for the user.

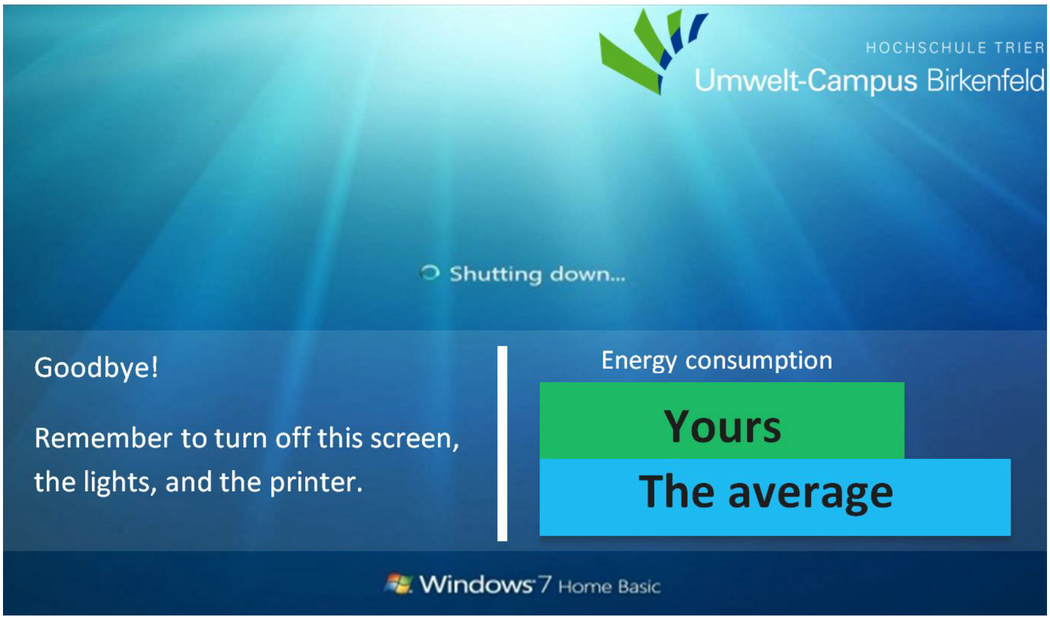

Figure 3
Feedback while shutting down a PC

Concerning the heating, we are about to develop electronic devices to help users to go green with the energy resources: Now we are working on a device named "REGENA-Pilot". This is a heat cost allocator, which will be able not only to count the energy consumption, but also to help the user with appropriate feedback, how the energy consumption can be reduced. For example, REGENA-Pilot will be able to tell the user that she/he should better close the window or lower heating, if she/he wants to reduce the energy consumption (in case the user opened a window when the HVAC is active: Energy wasting case). All this related work to reduce energy consumption will be a part of our REGENA-Model.

(5) Cost-benefit analysis: The strategies and methods of our REGENA-Model should be low-cost, but nevertheless very effective, so that more and more universities and others publics institutions can easily apply them. Therefore, we will take into account accurate cost-benefit analyses for all investments.

(6) REGENA-Model: Following the steps 1, 2, 3, 4, and 5 the REGENA-Model will be developed. The REGENA-Model has many components, such as acquisition and documentation sheets concerning the state of EnMS in universities, usage scenarios and usage profiles, comparative evaluations of transmission technologies for sensor values, as well as summary lists of suitable and proven low-cost measures. In addition, it includes the results of our related projects, such as REGENA-Pilot and others.

(7) Application of the REGENA-Model: To ensure the effectiveness and the transferability of the REGENA-Model, it will be tested at two universities (see above) with major differences in their current automation technologies, as well as in their buildings and structures. The results will be evaluated, analysed, documented, and then used to improve the REGENA-Model. The new model will be tested again in an iteration loop to optimise the model (*see figure 2*).

4. Conclusions

In our paper, we present a brief description how we will build the REGENA-Model, based on a robust SCADA-System. We describe the possible technical issues and our main research question, as well as other scientific issues. In the context of the REGENA research project, university-specific solutions will be developed and low-cost technical solutions and intervention measures to reduce the energy consumption will be tested and evaluated.

We are convinced that the REGENA-Model will serve as a qualitative approach for more energy efficiency in universities and possibly in public buildings, such as schools.

Acknowledgments

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Bibliography

Adunka, F. (2011): Handbuch der Wärmeverbrauchsmessung, Grundlagen, Methoden, Probleme, 4. Aufl., Essen, S. 344

Homburg, A., Mathies. E. (1998):Umweltpsychologie. Umweltkrise, Gesellschaft und Individuum, Weinheim und München

Liers, J., Person, R.-D. (2012): Energiemanagement in Hochschulen, Handbuch zur Unterstützung bei der Einführung eines Energiemanagements in Hochschulen, Hannover, S. i

Mack, B. (2007): Energiesparen fördern durch psychologische Interventionen, Münster, S. 60

Otto-von-Guericke-Universität Magdeburg, Institut für Psychologie I: Veränderung nachhaltigkeitsrelevanter Routinen in Organisationen (change), http://www.change-energie.de, 2013-04-04

Schwartz, S. H. (1977): Normative influences on altruism, in: Berkowitz, L. (ed.): Advances in Experimental Social Psychology, New York, pp. 221-279

Wicaksono, H., Rogalski, S., Kusnady, E. (2010): Knowledge-based Intelligent Energy Management Using Building Automation System, in: Institute of Electrical and Electronics Engineers (ed.): IPEC 2010, The 9th International Power and Energy Conference: 27-29 October 2010, Suntec, Singapore, pp. 1140–1145