ENERKENN: WEB-BASED METHOD TO GENERATE SPECIFIC ENERGY CONSUMPTION DATA FOR EVALUATION AND OPTIMIZATION OF OFFICE BUILDING OPERATION

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ABSTRACT

Insufficient concern about energy efficiency during the design and/or the operation of a building is the main reason for the high energy consumption of existing buildings. The knowledge of facility managers about the real energy consumption is often poor, regular documentation or analysis of consumption data are not existing. *Enerkenn* therefore intents to develop a procedure to record and evaluate relevant energy data and to find out energy saving potentials with environmentally conscious and economically reasonable accuracy. The main features are an internet based data monitoring and low investment costs for data acquisition or specialised software packages. In co-operation with the Track Infrastructure Stock Corporation of the German Railway Company (DB Netz AG) the method will be developed and tested with nine office buildings in usage of the DB Netz AG which are comparable in expanse, age and use.

KEYWORDS

Internet based monitoring of energy consumption data, specific energy and area values, office buildings, building stock, energy optimisation.

INTRODUCTION: MOTIVATION AND GOALS

Former projects on the documentation and analysis of energy consumption in office buildings focused either on recording a large number of objects [Ages 2001, Weber 1999] or on high resolution monitoring of data of single buildings [Voss 2001]. Results of the first study are not sufficient to evaluate the efficiency of technical systems or to develop optimisation concepts. Numerous, detailed information are gained in the second research project, but this strategy will remain unique because of high expenses in planing, data acquisition and analysis software. Because of (1) compact building structures, (2) large building volumes, (3) improved insulation standards, and (4) high internal loads caused by users and technical systems, the heating energy consumption is pushed into the background compared to increasing electricity consumption for HVAC, lighting, working aids, and other building services [Voss 2001, Weber 1999]. A reduction of CO_2 emissions can only be achieved, if the focus of strategies to reduce the total energy consumption of office buildings lies on the electricity consumption. For this reason, the main goals of *enerkenn* are concentrated on the technical potential, the building operation and the building users' behaviour in terms of energy saving. However, the reduction of energy consumption and operation costs of the nine analysed office buildings of the DB Netz AG has to coincide with the user comfort and the effective improvement of the energy and area management.

METHODS

Due to the way of generating comparable specific energy and area values the process developed for *enerkenn* can be used for fast and economic evaluation of energy consumption levels for a large number of buildings. It will also enable the development of targeted optimisation strategies with consolidated analyses of the building techniques in individual buildings. Fig.1 shows the two-phase process structure of the 3 sectors area analysis, energy analysis and services. During the first phase of the analysis (rough analysis), comparable specific energy and water consumption values as well as specific area values are generated for benchmarking, using a large number of buildings. Data used for this step are from different sources in order to reduce errors in a most possible way. The service part of the rough analysis is the integration of periodic consumption data logging in the buildings and the data administration and visualisation via the internet. Fig. 2 shows an excerpt of the online input form for weekly meter readings in the buildings, registered manually by the building technician, with automatically validity check and the simultaneous data hand-over of the visualised consumption data.

Fig.1: Two-phase process structure with the three sectors area, energy and service.

Fig.2: Online input form for weekly meter readings in the buildings and the data visualisation hand-over via internet for each building and all together.

During the detailed analysis period (see also with Fig.1), high deviations concerning energy and water consumption amongst the buildings are detected, using the web-based long-time monitoring of all energy registration devices in the buildings. Depending on the question of interest and desired analysis depth, varied components for further analysis can be chosen. For the part of energy analysis, mobile measurement equipment for short-time monitoring and the analysis of technical building services (HVAC, lighting, central services, et cetera) are available as well as energy demand calculations. The area analysis is refined by the registration of all different area types according to DIN 277, the calculation of the building envelope area and is then finished up by an individual area efficiency analysis. In the service part, an evaluation of the users' acceptance regarding the building characteristics is offered.

Analysed buildings

The nine buildings used for the development of these methods are situated in different towns in Germany and can be compared very well, regarding their age (years of construction 1995 to 2000), their really large expanse (mostly 22.000 to 31.500 m^2; 550 to 900 working spaces) and their usage structure (partly air-conditioned office buildings). Most of the buildings are long-time leased by the DB Netz AG, therefore the building operation is comparable too. Six buildings use 1/6 of their net floor area for additional technical usage, meaning the function as control room in fully air-conditioned open-plan offices with computer-intense, 24-hour use. Fig.5 explains the usage structure of the buildings. The efficiency increase of the technical systems and building operation as well as the users' participation in the evaluation process are the primarily optimisation approaches for the DB Netz AG holding the building lease, and agree ideally with the focus of *enerkenn*.

ROUGH ANALYSIS RESULTS

The relevant floor area (EBF) for generating specific energy consumption values is defined as the heated net floor area (NGF) of the analysed buildings, whereas for the not-heated usage area only the parking garages are not included (see also Fig.5). Meteorological influences are still to be extracted during this phase. Fig.3 shows specific consumption data of eight buildings (the building omitted is not yet completely used).

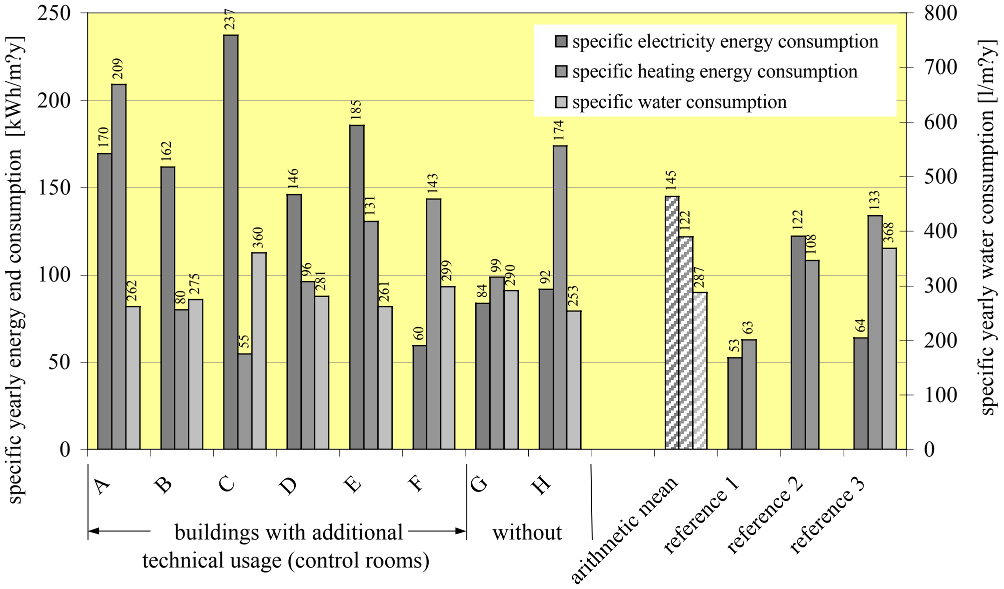

Fig.3: Specific yearly end energy and water consumption of the eight buildings (related to the heated net floor area; data measured one full year 02-2001 to 02-2002), compared to their arithmetic mean value and the results of three reference studies: Reference 1 shows the specific values of the low-energy office building of DB Netz AG in Hamm, monitored within the research programme SolarBau:Monitor [Voss 2001]; reference 2 shows the mean value of 100 registered office buildings in Switzerland [Weber 1999] and reference 3 the arithmetic mean value of a recent study in Germany of about 1600 office buildings [Ages 2001].

The electricity and heating consumption among the buildings show an unexpectedly high difference (factor 5 for electricity, factor 4 for heat), although they are used almost identically. The conspicuously low electricity consumption of building *F* is quite remarkable: With additional technical usage and without specially designed or technically managed reduction measures, the electricity consumption of this building is in the same order of magnitude as the low-energy office building of reference 1. Compared to the specific consumption values of reference 2 [Weber 1999], the average values are approximately 20 % higher. Compared to reference 3 [Ages 2001], all buildings show a much higher consumption level for electricity, but a slightly lower consumption level for heat. Buildings *A* and *H* with the high heating energy consumption are designed with a full-glass entrance hall (building *A*) and a full-glass facade (building *H*), whereas building *B* with the not-heated glass atrium shows a very positive heating energy consumption behaviour. The saving potentials summed up over all buildings compared to the arithmetic mean are 175 kWh/m^{2}y for electricity and 169 kWh/m^{2}y for heating energy. This is the same order of magnitude as the consumption of a building with a rather worse energy consumption level would have in total. Monetarily valued, the saving potential for electricity of all buildings (1.8 Mio. Euro/y in 2001; 8 Cent/kWh assumed) is three times higher than the costs for heating and ten times higher than the costs for water.

First Experiences concerning the developed method

The experiences with the rough analysis phase were critically questioned regarding the co-operation with the DB Netz AG, work expenditure and work methods. The buildings consisted of surprisingly poor data of both, area values as well as historic consumption data and energy costs. The data supply and collection (areas, consumption before the beginning of the project, costs) required twice as much time as planned. The co-operation with the staff in the buildings strongly depends on the personal motivation and knowledge of the responsible person. Already after a two-month test period, the co-operation and the work methods of the weekly consumption data monitoring has proven to be quite practical and free of problems. The methodical structure in only a few components before the final benchmarking in the rough analysis phase reacts to these experiences.

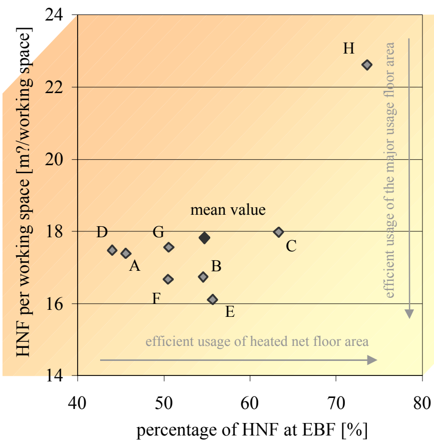

Fig.4: comparison of efficient usage of the heated net floor area (energy relevant area EBF) and major usage floor area (HNF) working space

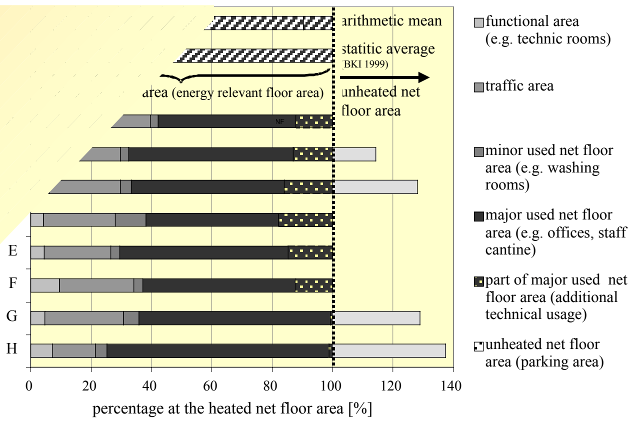

Fig.5: percentage of different used areas within the heated net floor area (energy relevant area EBF) of each building, compared to the mean and the german average

OUTLOOK TO PLANNED RESULTS IN THE DETAILED ANALYSIS PERIOD

All nine buildings will be part of the area efficiency analysis during the detailed analysis period, because of the grown interest of DB Netz AG. In contrast, for the detailed energy analysis only the three buildings with the highest annual overall primary energy consumption were selected (building *A,C* and *E*) and compared to the best building (building F).

Detailed area efficiency analysis

Based on standard building area registration (DIN 277) an analysis in efficient use of the buildings areas could be done so far for eight of the nine buildings. Fig.5 describes the varying percentages of building zones with different usage within the heated net floor area, defined as energy relevant area (EBF). The percentage of circulation area (VF) and functional area (FF), e.g. technique rooms, varies between 20 to 30 % of the energy relevant area and is, depending on the design and the high effort in technical services, clearly higher than the statistic average in Germany (BKI 1999). The not-heated garages can reach up to 30 % of the energy relevant area as in case of building *H*. Fig.4 estimates the efficient use of the building areas related to the utilisation of the energy relevant area on the one hand and the efficient usage of the major use floor area (HNF) by working spaces on the other hand. Building *H* is remarkably out of the range of the other buildings because of its high percentage of open-plan offices with inadequate low utilisation of their internal multifunctional zones.

Detailed analysis of the technical system and calculation of heating energy demand

The weekly consumption data logging allows a differentiation of the yearly consumption into mean daily consumption data for electricity, heating energy and water consumption. Fig.6 shows the time series of the specific electricity consumption during one full year for each building.

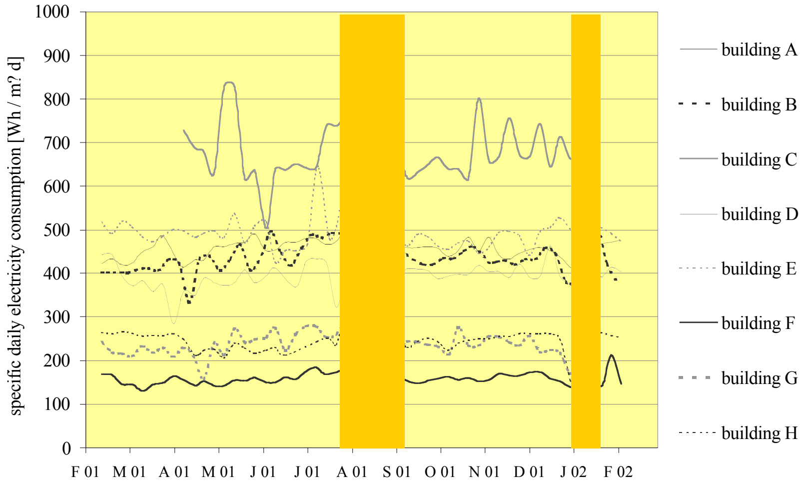

Fig.6: Comparison of the mean daily specific electricity consumption on the base of weekly consumption data of the eight biuldings during one full year (data measured in the period between Feb 2001 to Feb 2002)

The focus during further observations will lie on the seasonal variation and any of their possible dependence between electricity, heating and water consumption. Conspicuously and furthermore interesting for future analysis are the different variances in the consumption levels of some buildings or the strong and in most buildings similarly existing variation of the electricity demand in hot summer times (dark grey column in the middle).
Individual electricity consumers (HVAC, lighting, technical services) are analysed separately by quantifying their specific power rating data for each part of the building. For example, Fig.7 shows the specific air exchange rates for six different ventilated zones of building *E* and relates them to the according building area. Fig.8 uses building *E* as an example to compare

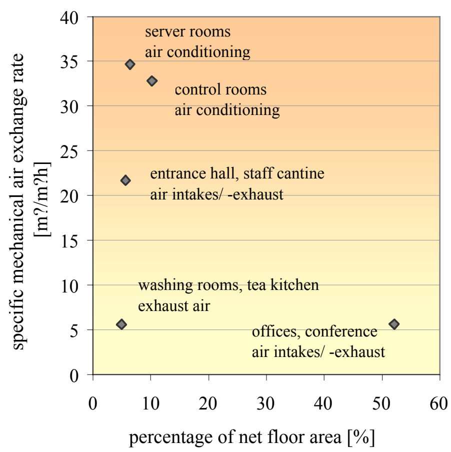

Fig.7: specific hourly air exchange rate over the supplied percentage of the net floor area in building E

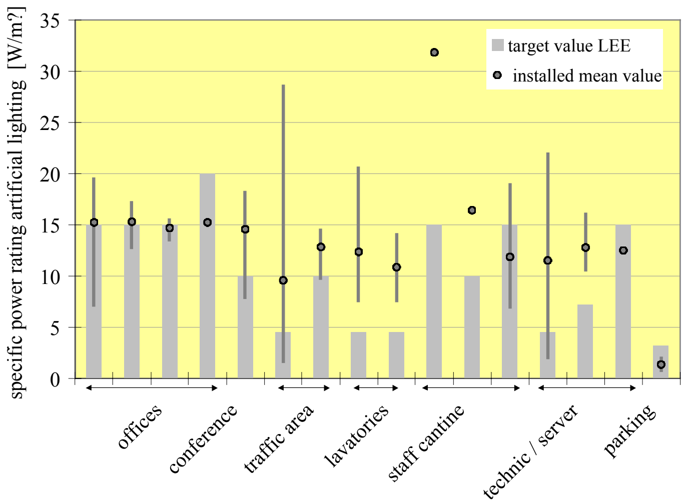

Fig.8: Variance and averagely installed specific power rating data of artificial lighting compared with target values (LEE) in building E

the installed specific power rating data of artificial lighting (variance and average) in different building zones with the targeted moderate value according to LEE [Hennings 2000]. The example shows the well dimensioned lighting in the offices and the partly oversized lighting in the circulation area and technical rooms. In another step, the simulation tool RADIANCE is used to survey regular office rooms for their usable daylight potential. Due to the gained information, an assessment of the electricity demand for artificial lighting will be possible.

Using a simple monthly calculation sheet following EN 832, the heating demand will be specified for each building and the quality of the thermal envelope will be gained. The calculation of the heating energy demand ensures the isolated view of the building zones, e.g. the additional technical usage, and in this way the influence of different air exchange rates can be shown. E.g. in the parts of building *E* with intensive ventilation (additional technical usage /server on about 16 % of energy relevant area, see Fig.5,7) the heating energy demand is 268 kWh/m^{2}y, approximately 100% more compared to the rest of the building (137 kWh/m^{2}y).

CONCLUSION

During the three years running time, the project *enerkenn* sets the main target in studying nine large office buildings for energy optimisation, accompanied by the development of a strategy to analyse numerous existing office buildings. The effort for ascertaining solid specific energy and area data, the detailed analysis of the area requirements and, finally, the co-operation with the buildings' responsible persons are aspects of first experiences. The developing method will promise qualities particularly in (1) an overall basic approach for recording and understanding buildings, (2) the transparency and adaptability as a result of the modular two-phase concept, further (3) the quality of solid specific building data by the use of comprehensible data and again, (4) the use of the internet in the function as a sustainable data logging and visualisation system in the buildings (see www.enerkenn.de). In the second part of the project time, the main focus will lie on the improvement of varies components for the detailed analysis. Detailed information gathered by mobile measurements and the evaluation of the user inquiry will estimate interesting aspects in terms of possible relations between user behaviour and the quality of the energy efficiency or the building operation. Finally, it is planned to value the cost effectiveness of each module and the developed method in total.

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