Projektinfo **09**/2012

Detailed information on energy research

Placing rooms in the right light

Targeted daylight and optimised artificial lighting help to improve comfort

BINE Information Service

Regardless whether in the office, at home or in school, too little daylight or unfavourable lighting impair visibility in rooms and strain the eyes. Based on the example of schools and homes for the elderly, it was investigated how new lighting concepts and new lamp, luminaire and ballast technology can help to improve the situation. A measurement system was used to monitor the lighting and energy properties. The new lighting systems and optimised technology enabled the electrical energy requirements in a school to be reduced by around two thirds.

Natural daylight is essential for ensuring wellbeing. Although rooms sufficiently illuminated with artificial light can support people's day and night rhythm, they cannot replace daylight. This rhythm is determined by a kind of inner clock that is considerably influenced by light. If the effective radiation is insufficient, this throws the inner clock out of kilter. This results in less pronounced sleep-wake phases and has a considerably negative effect on people's health and wellbeing. In order to keep this chronobiological rhythm in balance when insufficient daylight is provided, artificial lighting can be dynamically adjusted during the course of the day. In addition, new, optimised lighting and ballast technologies enable considerable energy savings to be made. In a joint project, researchers first of all determined how and to what extent the lighting efficiency can be improved. The existing antiquated systems were replaced with new lamp, luminaire and ballast technology as well as with energy-optimising control systems. This enabled them to reduce the energy required by an impressive two thirds.

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Quality parameters and light-related values

Good lighting requires that a lighting system takes into account all relevant quality parameters and does not just limit itself to one particular feature, for example the illuminance. Reading a book, assembling complicated components or working on the computer: different recreational or work activities determine the tasks that the eyes have to cope with. This in turn determines the requirements regarding the quality of the lighting. The brightness level and distribution, glare control, light colour and direction as well as the colour rendering are all light-related quality parameters. The European standard DIN EN 12464-1 "Lighting of work places – Part 1: Indoor work places" has expanded the quality definition. The standard quality parameters are now supplemented with aspects concerned with daylight use and the energy efficient generation of light.

The illuminance is measured horizontally and vertically in Lux (lx) and indicates the luminous flux that hits a specific area from a light source: around 100,000 Lux (lx) is measured in sunlight, roughly 10,000 lx is measured in the shade of a tree, 0.2 lx is measured on a moonlit night and even less from starlight. In interior spaces, the illuminance varies between 50 and 500 lx.

Fig. 1 *Typical existing situation with grid luminaires including fluorescent lamps and low-loss ballast devices: Left in the old building, right in the extension. Source: TU Berlin*

Training minds and eyes

In recent years experts have increasingly focussed on the lighting in school buildings. This is now considered to be an essential factor in promoting health and well-being and contributes to successful learning. For example, with 74.5 MWh p.a. the energy requirements at the investigated Königin Luise School in Berlin-Dahlem were more than double as high as the comparison value for a reference building designed in accordance with the German Energy Saving Ordinance (EnEV 2009). The school was therefore selected for an exemplary refurbishment. As part of the investigation, newly developed decentralised measurement technology was used to monitor eight classrooms for more than a year.

Four buildings are situated on the school premises: an old building with teaching spaces and boarding facilities, a sports hall, a further extension with teaching spaces and a new building that houses the primary school. The investigation focussed on classroom pairs in the old building that were as similar as possible in terms of their construction. The various room pairs differ in terms of their orientation and the degree of lighting obstructions. With around 32 m^2 and an average of 20 pupils per class, the classrooms are relatively small in comparison with the teaching spaces in other schools.

Grid luminaires were previously installed in these classrooms with fluorescent lamps and low-loss, conventional ballast devices (Fig. 1); there was no blackboard lighting. In one room in each of the room pairs being investigated, so-called learn-promoting lighting was planned with a particularly high colour temperature (8,000 K) and illuminance (500 lx). For this purpose four luminaires (light output ratio: 69 %) were installed, each of which has three 35 W T5 fluorescent lamps. In the neighbouring room, on the other hand, particularly energy-efficient lighting was planned with a standard-conforming illuminance of 300 lx above the worktables (Fig. 2). For this purpose, four energy efficient luminaires (light output ratio: 94 %) were installed, each of which has a 35 W T5 lamp. Blackboard lighting was retrofitted in all rooms, which can be switched on manually as required. The lighting systems in all rooms were equipped with a presence- and daylight responsive lighting control system. The control system is programmed to an illuminance of 300 and 500 lx and automatically switches off the lighting ten minutes after people have left the room.

With 24.8 MWh p.a., the annual energy requirement of the newly planned lighting system undercuts the stipulated value of 35.2 MWh p.a. (according to EnEV 2009) by around one third.

The newly planned system therefore saves two thirds of the lighting energy used by the old lighting system, whereby the energy savings in this school are spread across various measures: The greatest savings potential lay in the energy efficient lamps, luminaires and ballast technology. They made up more than half of the savings (approx. 60 %). Around a third of the savings were achieved just through installing presence detectors. The daylight responsive lighting control system provides around 10 % of the savings.

Based on these investigations, guidelines will now be drawn up by the respective standardisation bodies in the DIN Lighting Technology Standards Committee (FNL) and the Deutsche Lichttechnische Gesellschaft (LiTG). For this purpose, lighting designers, architects and medical practitioners have developed a scientific basis for the German lighting industry. Moreover, a cross-sectional analysis of 48 schools with 86 buildings has shown that there is a considerable need for refurbishment among school buildings built before 1990.

Fig. 2 *Lighting situation in the classrooms after installing the optimised lighting and ballast technology: Left the energy efficient and warm white (4,000 K) lighting, right the learn-promoting bluish lighting (6,500 K). Source: TU Berlin*

Lighting in need of care

Many homes for elderly people have not been refurbished and are often equipped with inefficient lighting systems that do not accord with energy requirements or health aspects. In this part of the joint project researchers investigated and assessed the lighting situation in two retirement homes in Berlin. The concept behind the homes is that the residents should spend as little time as possible in their own rooms during the day. For this reason most spend almost the entire day in centrally located, large-sized common rooms. Quantitative surveys were conducted with the residents in the retirement homes in regards to their comfort and meeting visual tasks. The evaluations were based on surveys with various scenarios for general lighting with two different colour temperatures for the lamps used (warm white: 3,000 K and cool white: 6,500 K).

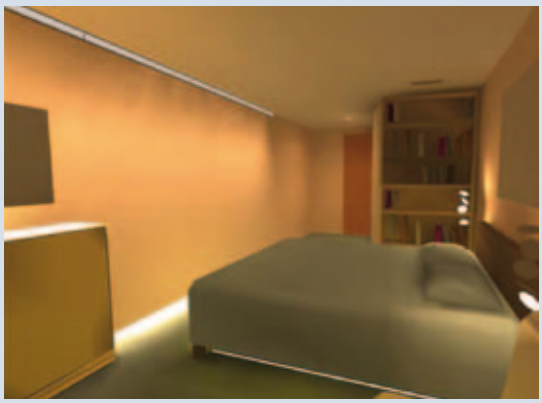
Here it was shown that warm white light with a vertical illuminance of just 100 lx was felt to be pleasant during the mornings and afternoons both in winter and early spring. Values of 500 lx and more were felt to be too bright. In the case of the cool white lighting, the respondents tended to find this too cool at the beginning of the year but found it just right during the other months. However, the residents found the vertical illuminance of 100 lx to be too dark from summer to December.

When presented with large-sized texts (Arial, 14 pt), all respondents assessed their reading ability as „good“ under all lighting conditions, i.e. for both the warm and cool white light, and with all applied horizontal illuminance from 150 to 1,000 lx. However, with small and medium font sizes (Arial, 12 and 10 pt), the appraisals were more differentiated: whereas 80 to 90 % of the respondents described their ability to read texts with 12-pt fonts as „good“ for all lighting conditions, in the case of the smaller text (10 pt) the cold white lighting was found to be better than the warm white lighting.

Light on board

Most cabins in cruise ships are situated on the inside, which means that artificial light has to replace daylight. However, non-controllable halogen bulbs and (compact) fluorescent lamps ignore the natural light rhythm. This conventional lighting also has the disadvantage that a diverse range of different replacement bulbs has to be transported as well. Replacing conventional lighting with modern LED solutions can reduce the energy requirement of the lighting by around 25 %. This means that a ship with four diesel generators would be able to dispense with one of them.

A particular aim of the sub-project on energy-optimised lighting was to imitate the change in daylight during the day in internally located ship's cabins. At the start of the day the light is designed to animate the guests on board, whereas in the evening it is designed to bring the day to a close with a relaxed ambience. To achieve this, the lighting strength, light density distribution and light colour are variably adjusted. The light colour is continually changed between warm white (2,700 K) and daylight white (6,500 K) light. A prerequisite is that the ceiling and walls are bright and neutral in colour so that the indirect lighting "functions" and is not distorted in terms of the colour. A separate control of the wall and ceiling lamps enables the light distribution to be changed in the room.



Lighting scenarios in a ship's cabin with variable LED lighting: Above „Good morning“, below „Good evening“. Source: TU Berlin

Architectural and energy optimisation

In Germany there are around 12,000 homes for elderly people with more than 840,000 places for the elderly and people in need of care. Around half of these homes have not been modernised in the last 20 years. Particular disadvantages of the buildings include their antiquated construction, lighting systems, building services equipment and plant technology. Increasing energy costs have also become a tangible cost factor in retirement and nursing homes, and present operators and funding bodies with the task of reducing costs and using energy efficiently while maintaining the same quality standard. State-of-the-art buildings are essential if residents are to feel comfortable in an institution. Faced with the demographic change and the increase in nursing costs, refurbishment concepts for nursing accommodation are an essential task for the future.

As part of a joint project, researchers are therefore developing concepts that contribute to holistic, sustainable and energy-based refurbishment measures and to the further architectural development of residential care facilities. In collaboration with the Centre for Sustainable Energy Technology (zafh.net) at Stuttgart University of Applied Sciences and further partners, the intention is to develop energy-based, health-promoting, economic, ecological and design-based solutions, and to compile them in formative guidelines for assessing the feasibility and evaluating sustainable refurbishment concepts.

The current project forms part of the „Energy-Optimised Construction“ (EnOB) research initiative. Together with Osram and the Evangelisches Altenzentrum in Bruchsal, the project is scheduled for completion in 2016. It is the second flagship project in the field of old-age care provision to be funded by the German Federal Ministry of Economics and Technology and is intended to provide a comparison basis for all other institutions with similar uses.

In this project the building services will be replaced with new, efficient components that are based on an intelligent building automation concept and which work with renewable energy sources. This will therefore lower the primary energy requirements for heating. After implementing the new systems, they will be monitored for two years, which will enable forecasts and measurement values to be compared with the actual operation and ultimately enable the final operation to be optimised.

Project participants

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Links and literature

- www.licht.de/en/
- Innovative Schools – Scientific Education Centre. BINE-Projektinfo brochure 07/2009
- Building refurbishment – Children’s day care centre. BINE-Projektinfo brochure 10/2006

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