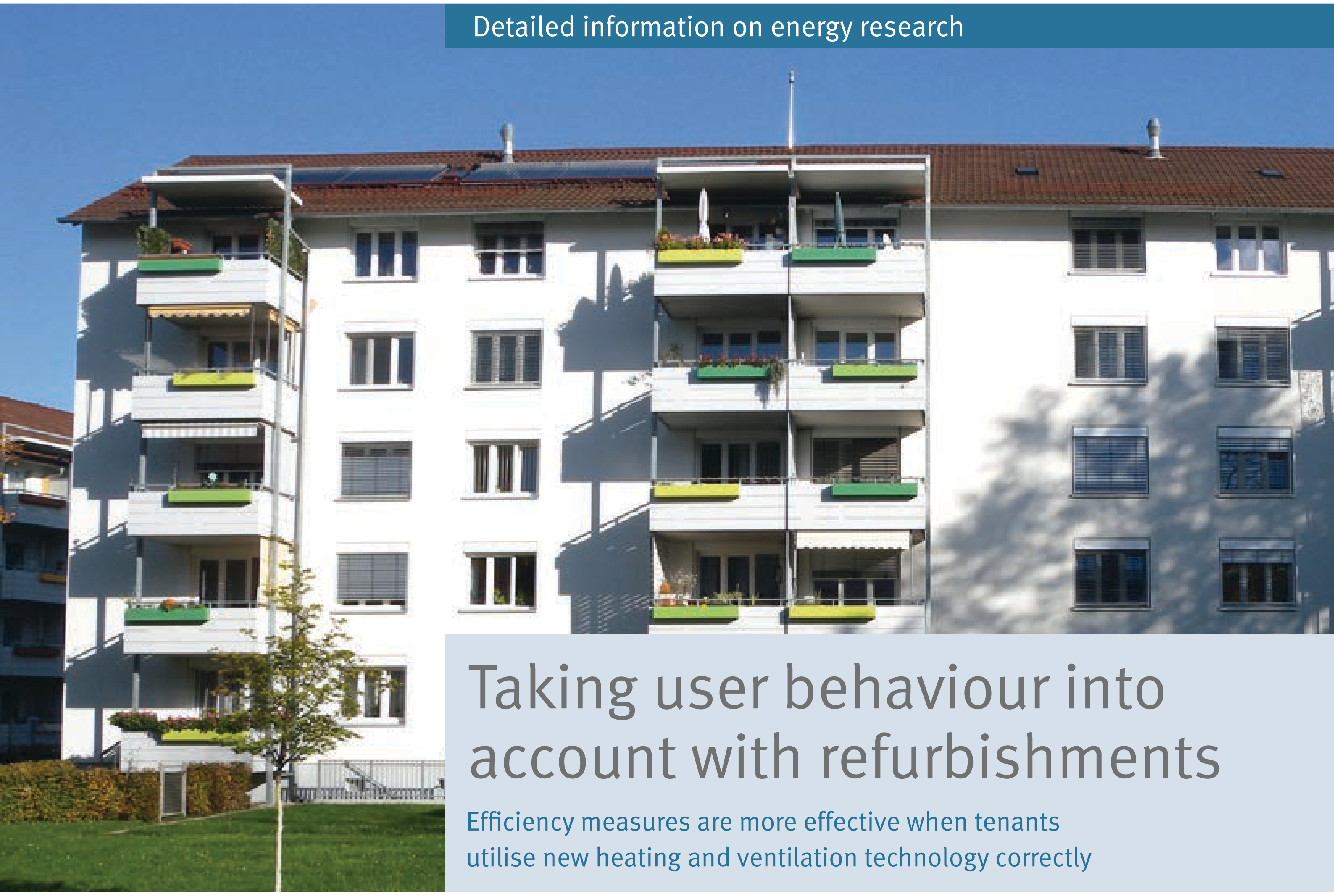
Projektinfo **02**/2015

Detailed information on energy research



Taking user behaviour into account with refurbishments

Efficiency measures are more effective when tenants utilise new heating and ventilation technology correctly

BINE Information Service

With the refurbishment of a residential neighbourhood in Karlsruhe everything was done correctly in theory. Nevertheless, the consumption values measured in three investigated buildings are up to 25 per cent higher than the requirement values calculated prior to the refurbishment. Scientists at the E.ON Energy Research Centre at RWTH Aachen University are investigating the causes of this so-called "rebound effect".

Before building owners opt for a specific refurbishment alternative they analyse the possible energy and cost savings. It is often the case, however, that the actual consumption after the renovation is higher than the energy requirement calculated in advance. The energy savings expected from the refurbishment do not materialise. Among other things experts attribute this to the so-called rebound effect. This happens when changes in behaviour occur as a result of technical improvements to the energy efficiency. These can reduce the original positive effect or have completely the reverse effect, for example if users want higher indoor temperatures after the refurbishment than before the refurbishment.

Researchers are investigating why expected energy savings do not materialise using the example of a residential neighbourhood in Karlsruhe. Here an integral overall energy concept is being developed and implemented for almost 800 residential units. The aim is to find a combination of economically optimal refurbishment measures for improving the energy efficiency while realigning the heating provision. The scientists are investigating the potential savings provided by energy efficient refurbishment on three selected apartment blocks (Fig. 1).

This research project is funded by the

Federal Ministry for Economic Affairs and Energy (BMWi)

Refurbishment measures vary

"The apartment blocks are ideally suited for research purposes because they are built in exactly the same way and all have the same geographical orientation," explains Tanja Osterhage, project team member in the research project entitled "Auswirkungen des Rebound-Effekts bei der Sanierung von Bestandsgebäuden " (Effects of the rebound effect when refurbishing existing building stock). There are a total of 90 renovated apartments in which seven different refurbishment alternatives were used.

Osterhage: "The first block is used for comparison purposes, as only the standard refurbishment method deployed by the owner, Volkswohnung Karlsruhe, was implemented here. Here we only carried out evaluations for the overall balance. These values enable us to identify general trends." The buildings were clad with standard thermal insulation panels (U = 0.22 W/(m²K)). Heat for space heating and domestic hot water is provided by the newly created district heating network. The apartments are supplied with heat via radiators. There are air inlets in the window frames and exhaust air is discharged through the kitchens and bathrooms.

In contrast to the first block, the structural fabric- and system-based components also vary with the two other building complexes. The second block is designed as a "three-litre house". The scientists used thermal insulation with a thermal conductivity λ = 0.022 W/(mK). Standard windows (U_w= 1.3 W/(m²K)) and Passive House windows (U_w= 0.8 W/(m²K)) were used. The buildings are connected to the district heating network and received different decentralised ventilation systems and domestic hot water production systems.

The third block serves as a research building. In this Passive House scheme the project members deployed different innovative materials and system-based combinations. There are therefore several differences between the three different building sections in this block (Fig. 2).

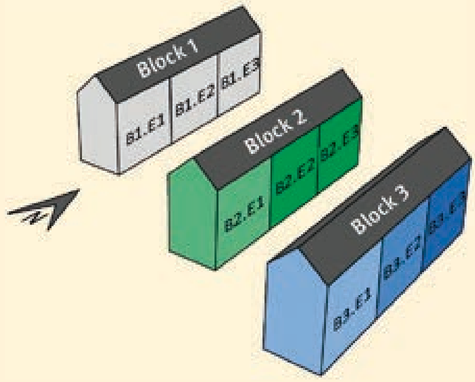


Fig. 1 *The researchers are conducting their measurements on three apartment blocks, each of which has three separate entrances (E1, E2, E3).*

Building sections Block 3	Entrance 1	Entrance 2	Entrance 3
Facade insulation	U=approx. 0.11 W/(m²K)		
Windows	U_w =approx. 0.8 W/(m²K)	U_w =approx. 0.8 W/(m²K)	U_w =approx. 1.3 W/(m²K)
Top floor ceiling	U= 0.14 W/(m²K)		
Kellerdecke	U= 0.24 W/(m²K)		
Heating	Heat pump with CO_2 probe	2 heat pumps, CO_2 probe	Heat pump air/ split modulating, exhaust air heat pump
	Space heating using underfloor heating	Decentralised ventilation devices with heat recovery and back-up heat exchanger	Ceiling heating/ cooling
Domestic hot water	Low-temperature DHW, decentralised as apartment freshwater station		
Ventilation	DDecentralised ventilation devices with heat recovery	Central ventilation equipment with heat recovery in roof space, Each housing unit has a ventilation unit with heat exchanger	Central exhaust system, overflow openings in window frames, heat recovered by feeding exhaust air

Fig. 2 *Various refurbishment alternatives have been implemented in the third apartment block. The scientists have tested materials and system-specific combinations that are not deployed as standard.*

New technology and user satisfaction tested

The University of Karlsruhe installed comprehensive measurement technology as soon as the integral energy concept was implemented for the entire district Karlsruhe. The researchers can currently use this to test the efficiency of the system technology and user behaviour and to draw conclusions about the success of the modernisation measures. Basic values for the domestic hot water, space heating and ventilation are recorded in all apartments. These values enable the researchers to evaluate potential distribution or storage losses. In addition, they are collecting data on the room temperature, relative humidity, window opening behaviour and air quality. The measurements provide 6 million datasets per day, which are incorporated into a database. In order to depict the values in relation to the tenant behaviour, the scientists conducted a questionnaire-based survey. The survey questions focussed on the ventilation behaviour and the room temperature. In addition, they investigated the extent to which the tenants accepted the new heating and ventilation systems and their level of satisfaction with the energy consumption and resulting comfort.

Consumption values higher than expected

After the modernisation, the actual primary energy consumption values were higher than the requirement values previously calculated for all building complexes (Fig. 3), whereby the more extensive the refurbishment of the technical systems and building fabric, the greater the disparity. The smallest differences occur in the first apartment block and the biggest difference is with the research apartment block 3. The analysis of the heating energy consumption shows that considerable differences partially exist between individual apartments in all the buildings. This can be illustrated by way of example with apartment block 2 (Fig. 4). Here there is one clear outlier with high energy consumption values, high indoor temperatures and moderate ventilation behaviour. There are also, however, rental apartments with high consumption which, although they do not have high indoor temperatures, have windows open almost two-thirds of the time. One tenant has high energy consumption and high indoor temperatures with moderate window opening behaviour. The neighbours have approximately the same temperatures in their homes but a significantly lower consumption.

Technical problems generating dissatisfaction

The fact that the expected energy savings did not materialise is due to both technical and social reasons. In a survey, only half of the tenants stated that the operation of the new system technology was more comfortable than before. In the research building complex there were complaints about too

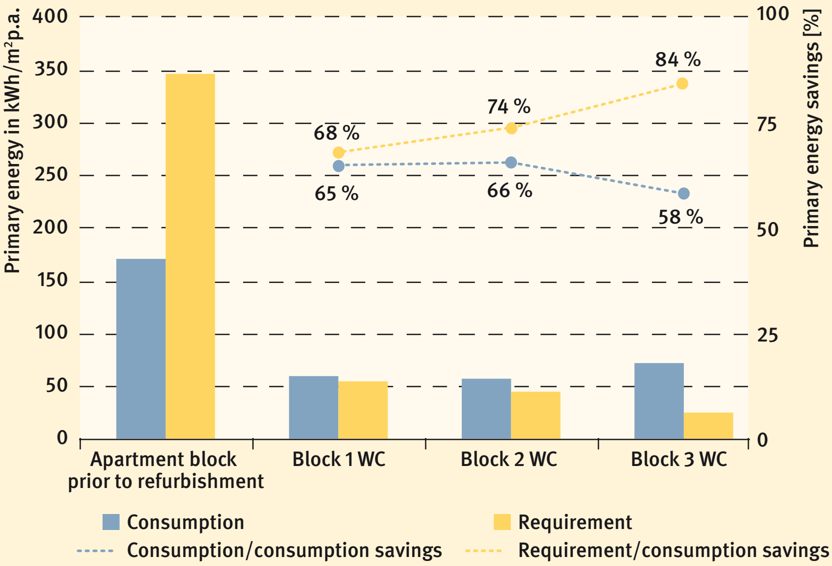


Fig. 3 *The primary energy consumption before refurbishment (blue bar) was higher than after the refurbishment (yellow bar). The savings are less than expected.*

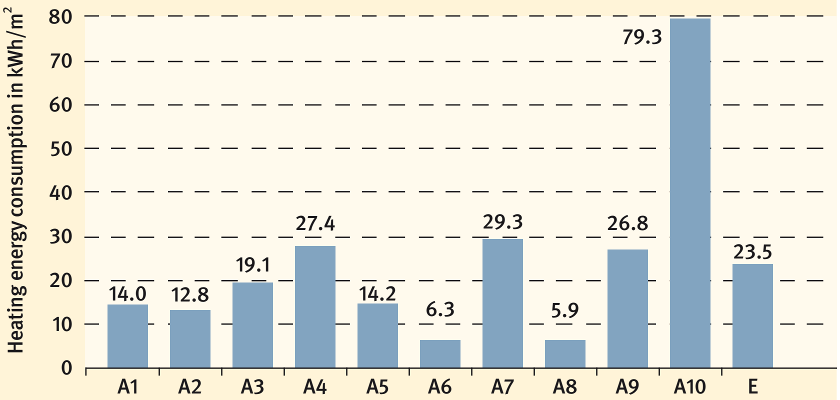


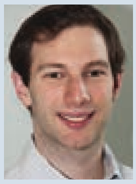
Fig. 4 *With the second apartment block, the ten apartments belonging to Entrance 1 have an average heating energy consumption E of 23.5 kWh/m².*

low and highly fluctuating domestic hot water temperatures as well as unsatisfactory indoor temperatures. “We can explain this in part by the fact that, compared with the other blocks, the most ventilation technology is installed in apartment block 3 and the building is partly heated using air heating. As a result, there are fewer heat radiating surfaces in the apartments and subsequently a reduced feeling of comfort,” says Osterhage.

In addition, technical problems ensured that the tenants were dissatisfied. The heat pumps malfunctioned in apartment block 3. Improving the loading strategy for the hot water buffer storage tank and reducing the useful heat temperature managed to improve the performance factor of the heat pump for entrance E1. The heat pump for entrance E2 has been replaced by a module with a variable-speed compressor and a new control strategy has been implemented. The heat pump now has better coefficients of performance. Among others, leaky heat exchangers and defective ball valves were repaired in the domestic hot water stations in the second apartment block.

The tenants often use the new technology according to their accustomed habits. For example, they place the mixer taps for the domestic hot water in the accustomed previous position. Because the flow temperatures have changed, however, they receive water with lower temperatures. Some of the tenants do not use the ventilation systems at all because they fear higher energy costs.

Interview



Florian Heesen, project manager for the research project entitled “Analysis of user behaviour in energy efficient residential buildings” at RWTH Aachen University.

In your research you discovered that a high heating temperature did not necessarily imply a high energy consumption in all buildings. How do you explain this phenomenon?

We have observed, for example, that the window opening behaviour has an impact on the energy consumption. In addition, the energy consumption depends on the position of the respective apartments in the building and the indoor temperatures of adjacent rooms. The heating energy flows much more within the building rather than escaping out of the building through the external walls. This is due to the very good insulation provided by the envelope and the unchanged structural fabric within the building.

Did you manage to establish a link between the tenant satisfaction and the respective refurbishment alternatives?

Qualitatively speaking, our analyses show that the simpler it is to use a system, the greater the satisfaction of the residents. However, the satisfaction also depends to a large extent on the expectations. In other words, technology that does not work, or works differently than the expectations, has a considerable impact on the tenant satisfaction, whereby the expectation relates not only to properly functioning technology but also to the touted financial benefits!

What recommendations do you have for dealing with tenants during refurbishment projects?

The tenants form a substantial interest group with refurbishment projects. It is therefore important to involve them in the entire process and to develop systems for processing feedback as effectively as possible. Important in this regard are systems that allow information to flow in both directions, in other words from the investor to the tenant and vice versa. The most important feature of such systems is whether they facilitate an effective exchange of information.

The project in Karlsruhe is only one of many examples where potential energy savings were unable to be completely exhausted. To ensure that this works better in future, the scientists are currently developing coefficients and user typologies. These should be taken into account when calculating potential savings. Building developers therefore receive a realistic basis for evaluating their refurbishment measures.

Learning from the rebound effect

The investigations presented here on the rebound effect are being carried out in a residential neighbourhood in Karlsruhe. Here an integral overall energy concept is being developed and implemented for almost 800 residential units. The aim is to find a combination of economically optimal refurbishment measures for improving the energy efficiency while realigning the heat supply. In addition to achieving cost savings, the project participants are endeavouring to minimise the primary energy use and CO_2 emissions. It is intended that the overall monthly rent, including ancillary costs, should only increase very slightly. An important goal for the investors is to improve the attractiveness of the residential neighbourhood for tenants and other users, and thus ensure a return on its investment. A local heating network has been developed that is fed with CHP and exhaust heat. In addition, most of the 38 buildings have been modernised in an economically optimal manner. The buildings are between 37 and 56 years old.

The residential neighbourhood in Karlsruhe is just one of many projects endeavouring to increase the energy efficiency in urban areas. Important potential lies here in the refurbishment and modernisation of existing building stock. However, the rebound effect particularly occurs with such older buildings: with existing building stock the disparity between the energy requirement and consumption is greater the older the buildings are. This is because input parameters that are to some extent accepted and specified in the calculation methodology increasingly differ from the values that actually occur in reality. Particularly sensitive input variables have proved to be the indoor temperature, U-values, thermal bridge calculations and the air exchange rate.

It can be generally ascertained that it is evidently not sufficient to focus purely on energy efficiency measures. According to the research results, increasing the energy efficiency in the building sector alone is not necessarily enough to reduce the overall energy consumption and additional measures are required. When designing structural fabric- and system-based components, planners and architects will need to take into account in future that the theoretically possible energy savings will be reduced as a result of the performance gap and rebound effect.

Project participants

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