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A REFURBISHMENT CONCEPT FOR LARGE BUILDINGS CONSIDERING THE GERMAN ENERGY-SAVING DIRECTIVE "ENEV" DEMONSTRATED AT A NURSING HOME IN BRUCHSAL, GERMANY

KONCEPCJA MODERNIZACJI DUŻYCH BUDYNKÓW UWZGLĘDNIAJĄCA NIEMIECKIE ROZPORZĄDZENIE DOTYCZĄCE OSZCZĘDNOŚCI ENERGII (ZNANE JAKO ENEV) NA PRZYKŁADZIE DOMU SENIORA W BRUCHSAL

Abstract

On the basis of elderly people's requirements and as a reaction to changing social structures, a number of old people's homes were built between 1950 and 1980 in Germany. The design of these buildings does not represent modern energy standards and is characterized by significant modernization potential. In this paper, a case study will be analyzed and three refurbishment scenarios based on the status quo will be presented and rated taking energy efficiency as well as the costs and benefits of the measures into regard.

Keywords: refurbishment, primary energy, EnEV, nursing home, old people's home

Streszczenie

W reakcji na wymagania osób starszych oraz zmieniające się struktury społeczne, w latach 1950-1980 na terenie Niemiec zbudowano wiele domów seniora. Projekty tych budynków, które nie reprezentują nowoczesnych standardów energetycznych, charakteryzują się znacznym potencjałem modernizacyjnym. W niniejszym artykule analizujemy wybrany dom, a także przedstawiamy i oceniamy trzy scenariusze modernizacji oparte o istniejący stan rzeczy, biorąc pod uwagę wydajność energetyczną oraz koszty i zalety stosowanych metod.

Słowa kluczowe:modernizacja, energia pierwotna, EnEV, dom seniora, dom pogodnej jesieni

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1. Introduction

As a reaction to the changing demographic situation in Germany by 1980, a number of big independent homes for elderly people ranging from 100 to 300+ inhabitants were built. In 2011, these big nursing homes represent around 40% of more than 11,600 homes [1]. As the elderly would be considered as those in need of all the services provided in one facility and full service, hospital-like atmosphere was created in the homes. Modern elderly people wish to structure their lives individually according to their capabilities and preferences, e.g. in small living communities which consider age-related deficiencies and assist them in their individual lifestyles [2-4]. Whereas standardised and effective refurbishing strategies for private homes and office buildings exist in Germany, only partial research was carried out on the energetic optimization of old people's homes. The problems of the existing standards and regulations include their interpretation of the applicable age deficit model [5] and the fact that they do not consider the complete nursing system [5] or even an individual need approach [7, 8]. Since 1977, the "Evangelisches Altenzentrum Bruchsal" has offered an extensive supporting network for the care of elderly people and those suffering from dementia. The entire property consists of three interconnected buildings. The "Dietrich Bonhoeffer house" and the nearly identical "Luise Rinser house" are both old buildings meant for refurbishment. They were supplemented with a new building which was attached to one end of the old twin complex and put into operation in 2006.

The long, seven-floor high old complex (see Fig. 1), with its gross floor area (A) of 26,977 m², gross volume (V_e) of 73,164 m³ and A/V_e ratio of 0.33, provides about 250 nursing beds and 30 apartments. The building substance and the building technology strongly need redevelopment. The energy supply concept and the building structure remain in accordance with the 1970s standards which is neither ecologically nor economically justifiable.

Fig. 1. Façade of the "Bonhoeffer house" (L) and the "Rinser house" (R)

Rys. 1. Elewacja „domu Bonhoeffera" (L) oraz „domu Rinser" (P)

2. Methodology

Whereas methods for the energy refurbishment of domestic housing, public buildings or office buildings are widely available, little is known about the refurbishment strategy to be applied for old people's homes. There are some significant differences in the approach resulting from the specific demands of the occupants, the procedures of refurbishment, funding opportunities as well as the internal structure and organisation of these homes. In the first step, the building properties and technical equipment of the status-quo old people's home had to be investigated in order to receive an energy consumption benchmark. Further on, the historical records of energy consumption, taken from energy meters and energy bills, were used to determine the overall yearly energy demand of the existing compound. At the same time, energy demand calculations according to the EnEV were carried out and compared to the existing data. For a closer thermal analysis of the details of the existing building envelope as well as the insulation status of the heat production and distribution system, thermographic photos were taken. A combination of these measures gives a clear picture of the energetic status of the existing building and the obtained results of building technology investigations were further processed for the setup of a weak spot list in terms of the energy efficiency of the old people's home. In order to give priorities to possible refurbishment measures, an integrated planning strategy had to be chosen. There were clear restrictions from the involved parties, such as home management on budget, time frame, senior specific demands or home specific infrastructure and organization. Taking these demands into consideration, three possible renovation scenarios are proposed and compared with the status quo in means of energy efficiency, CO_2 reduction and primary energy demand. The German Energy Directive (EnEV), used for energy comparison and for reference value calculations in this context, is based upon the Energy Saving Law (EnEG) explained in the German standard DIN 18599. It forces constructors to meet minimum standards of energy consumption in new and refurbished buildings. The EnEV allows for an energy combination of building technology with building envelope insulation measures and finally results in two main figures: the maximum allowed yearly primary energy demand of a building (QP'') and the maximum yearly heat loss for the total building envelope (HT'). The criteria for funding from the "Kreditanstalt für Wiederaufbau" (KfW) are directly related to the results of the EnEV calculations but refer to the values of a new reference building for new and refurbished ones.

2.1. Daily temperature value calculation

$$G_z = \sum_{n=1}^{z} (20 - t_{m,n})$$

where:

G_z – degree day number (GTZ) within the analysis period, Kd

$t_{m,n}$ – daytime average of outdoor temperature during one heating day ($t_{m,n}$ < 15°C)

z – number of days within the analysis period where t_m < 15°C

2.2. Corrected heating-energy consumption calculation

$$E_{VH} = E_{VgH} \cdot \frac{G_m}{G_z}$$

where:

E_{VH} – corrected heating energy consumption, kWh
E_{VgH} – heating energy consumption depending on outdoor temperature, kWh
G_m – long term average of annual degree days number, Kd
G_z – degree days number, Kd

3. Results

3.1. An analysis of the input results for the energy status quo definition

3.1.1. Transmission heat and energy conversion losses

Generally speaking, an outdated building technology was detected. With the exception of two condensing gas furnaces with 420 kW each for the new building and an 80 kW CHP plant, the efficiency of heat production (2 x 1,600 kW gas furnaces, 535 kW gas steam boiler for the kitchen and laundry facility) can be significantly improved. For the façade in general, high heat losses were detected. Windows, building corners and thermal bridges at the terraces will need special attention when being refurbished. The efficiency of the heat production technology (atmospheric gas furnaces, steam boilers) with a total capacity of 3,700 kW can be considerably improved just by the application of modern technology. A major problem is the poor insulation of the far-reaching heating and hot water distribution system and the missing automatic control. By the measurement of room temperatures, it could be detected that on average the real indoor temperature of the living rooms, due to different comfort requirements of elderly people, was 3°C higher than the values stated in the EnEV.

3.1.2. Energy consumption records (historical data)

Besides the total monthly gas consumption, heating energy for one of the old twin buildings (Luise Rinser) was recorded by the energy meters which were installed at the respective heating loops. For the second twin building (Bonhoeffer), no metered values exist. As the energy meters were not connected to any data-logging facility, only the data for 13 months of the internal storage of the two devices were available for analysis and comparison with long-term data. Long-term energy consumption data were only available as monthly gas consumption for the last 14 years. As these are total gas demand values, they represent energy consumption for heating, domestic hot water as well as steam production for the laundry facility and energy consumption for the kitchen. In order to separate the demand values in basic demand (constant gas consumption for hot water, the kitchen and the laundry) and ambient temperature-related gas consumption (heating energy), the obtained data had to be first distinguished between those before and after 2005 when the new building complex was added to the existing compound.

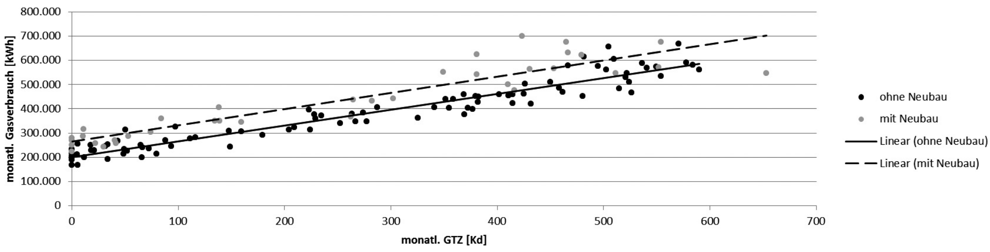

Fig. 2. Linear scheme of gas consumption values with and without new building

Rys. 2. Linearny wykres wartości zużycia gazu z nowym budynkiem/bez nowego budynku

In the second step, monthly gas consumption in the buildings was plotted in relation to the referring daily temperature values (GTZ, see 2.2) and the intersection of the linear points and the Y axes at x=0 gives the value for the basic consumption as GTZ = 0 (see Fig. 2). Figure 2 shows the yearly basic energy consumption value of the compound, including the new building (225,000 kWh) and excluding it (275,000 kWh).

3.1.3. Energy demand in the existing compound

Figure 3 shows total energy consumption from 1998 to 2005 for the two old buildings of 420,000 kWh/a on average. It is split up by a degree day analysis in basic consumption of 225,000 kWh/a and ambient temperature-related heating consumption of 195,000 kWh/a on average. The blue line shows the values for final energy consumption according to the EnEV-Calculation for the two old buildings which are slightly lower (390,000 kWh/a) than the measured values.

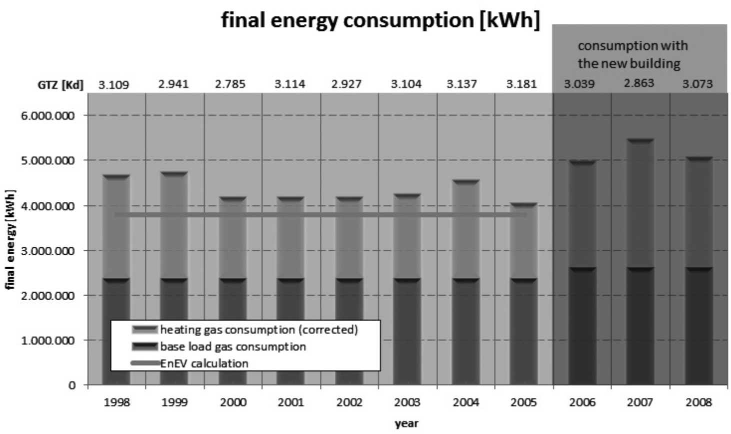

Fig. 3. Final energy consumption in the "Luise Rinser" and "Bonhoeffer" buildings

Rys. 3. Końcowe zużycie energii w budynkach „Luise Rinser" oraz „Bonhoeffera"

3.2. Prioritized refurbishment alternatives

Regarding the budget constraints given by the home management, two minimum solutions and one extended solution were considered. Firstly, a minimum solution for proceeding as the status quo with measures realized to enable home operation; secondly, a minimum solution to refurbish the building in order to achieve funds from the KfW. If further funding is available, a third energy-optimized solution could be considered and is therefore described here as well.

3.2.1. Further operation without energy optimization – low investment – no savings

In this scenario, no particular measures for improving the building envelope are carried out. Only broken parts, such as defective windows or leaking waterproofing, will be repaired and will have no effect on energy consumption. The transmission heat loss (HT‘) of this alternative will be 1.04 W/m²K. No additional measures for improving heat production, heat distribution and heat disposal will be considered, either. Only repairs of the distribution systems (heating and hot water) will be carried out in order to extend the operation time for at least five years.

3.2.2. KfW 100 funding – medium investment (funding) – significant savings

In order to receive KfW 100 funding for the building envelope, EnEV calculated maximum transmission heat loss (H_T‘) of 53.08 kWh/m²a has to be obtained which can only be facilitated by overall refurbishment (significant improvement of insulation, three window panes, extra attention to thermal bridges) of the ambient air touching envelope. For reaching KfW 100 standard besides H_T‘, the limit value for the yearly primary energy demand (Q_P‘‘) of the building technology of 69.60 kWh/(m²a) for heating and hot water production has to be kept., too To stay within this limit, a condensing gas furnace, decentralized hot water production, improved piping insulation by the improved envelope and radiators, lowered heating feed temperatures as well as a modern building management system and controlled ventilation with heat recovery have to be introduced in order to optimize the overall energy use and conversion efficiency. Due to the improved envelope and technology efficiency, one of the two old 1,600 kW gas furnaces can be shut off.

3.2.3. Maximum primary energy saving – high investment – low further savings, high environmental impact

This variant should show the potential of primary energy optimization in the home. Whereas the envelope will stay as in scenario B, the remaining 1,600 kW atmospheric gas furnace is substituted by a biomass one. With this measure, the Q_P‘‘ value can be reduced from 63.89 (scenario B) by 87% to 19.96 kWh/m²a.

To sum up, we can state that the transmission heat loss in the case study building is reduced to a half and the primary energy demand – to 42% (scenario B) or even to 13% (scenario C) compared to the status quo (Fig. 4).

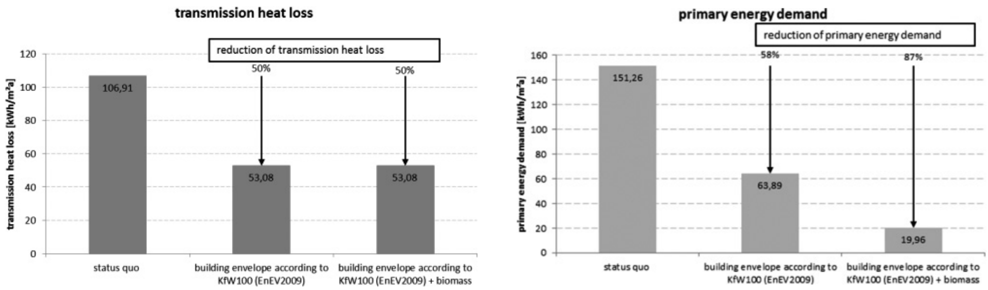

Fig. 4. Improvements of heat loss and primary energy demand in three alternatives

Rys. 4. Ulepszenia w zakresie strat energii cieplnej
i zapotrzebowania na energię pierwotną w trzech alternatywach

3.3. Economic comparison

The economic analysis and comparison was carried out according to the German standard VDI 2067 (annuity calculation method) for investment decision making, taking into regard detailed costs of refurbishment alternatives (see Fig. 5, Tab. 1). As boundary conditions the following values applied: observation period: 20 years; interest rate: 1,04 for capital-related cost (in scenario 2+3 1,015, because of KfW funding); price change factor for gas: 1,08, for biomass: 1,02; current gas-price 6,4 ct/kWh, biomass price 4,1 ct/ kWh; scenario 3: heat demand coverage: 80% biomass, 20% gas. For capital costs the following values apply: windows: 1.895.964 €; walls: 841.809 €; roof/terraces: 1.020.208 €; technical installations: 2.400.000 €; biomass furnace: 700.000 €. Operation related costs occurred for scenario1: 200.000 €/a; scenario 2: 50.000 €/a; scenario 3: 50.000 €/a.

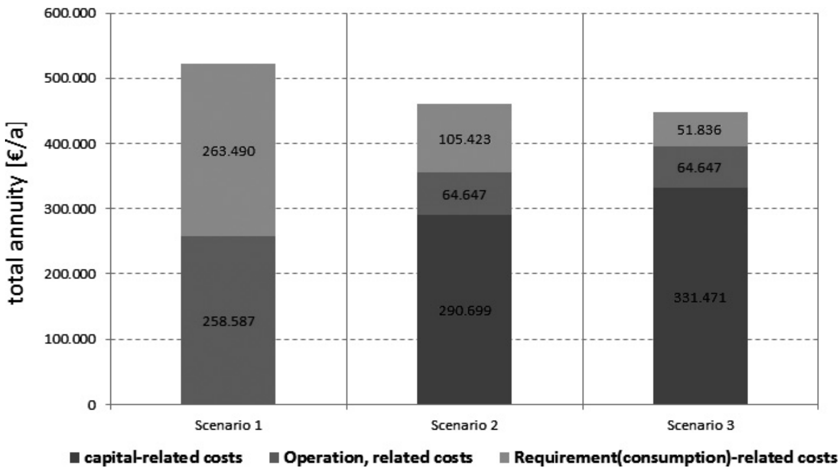

Fig. 5. Annuity comparison of the three alternatives

Rys. 5. Porównanie trzech opcji

3.4. Error analysis

Uncertainties in the analysis of the status quo definition as a benchmark for evaluating the alternatives occur due to a lack of detailed measured energy data. It could be observed that in Chapter 4.1. “Energy demand in the existing compound” the ambient temperature normalised heating demand Q_E calculated from the gas demand in opposite to the EnEV values and showed fluctuations which may be explained by numerous factors that cannot be defined in detail. The factors for variations could be that the base load, taken as constant in the course of the years, differs due to various uses of the laundry facility, the kitchen and the related hot water demand. Generally speaking, the heating energy demand depends on the occupancy of the home for which no information is available. These uncertainties also influence the economic analysis as the benchmark defines the starting point for payback calculations.

4. Conclusions

This paper describes a case study old people’s home and the methodology for analyzing the energy situation of an old, large living and nursing compound as well as compares measured and processed historical data with calculations according to the German EnEV regulations. Taking the final energy demand of the existing compound as a benchmark, three refurbishment alternatives are presented and investigated from the viewpoint of economy and energy. It could be shown that the alternative “KfW 100 funding”, despite high investment costs due to large energy cost saving and funding, reaches primary energy demand reductions at nearly 60% and gives a fast payback compared to the alternative “Further operation” respectively to the status quo. In the third variant, the primary energy saving potential of large old people’s homes is demonstrated by reaching reduction values of 87% compared to the status quo. There is a refurbishment potential of approximately 1,000 nursing homes (300+ occupants) built between 1950 and 1980 in former West Germany exclusively [9]. If, as an outlook, all these homes are retrofitted to the 2009 EnEV KfW 100 standard, approximately 87 GWh/m^{2}a corresponding to 19.14 t/m^{2}a of CO_2 emissions can be saved.

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Denotations

EnEV – Energie Einsparungs-Verordnung (Energy Saving Directive)
EnEG – Energie Einsparungsgesetz (Energy Saving Law)
zafh.net – Zentrum für angewandte Forschung an FHs (Centre of Applied Research)
BMWI – Bundesministerium für Wirtschaft und Technologie (Ministry of Economics and Technology)
EnEG – Energie-Einsparungsgesetz (Energy Saving law)
KfW – Kreditanstalt für Wiederaufbau (Loan Agency for Reconstruction)

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