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ENERGY MODERNIZATION OF TENEMENTS: FROM EXISTING STANDARD TO LOW ENERGY

MODERNIZACJA KAMIENIC CZYNSZOWYCH: OD POZIOMU OBECNEGO DO STANDARDU NISKOENERGETYCZNEGO

Abstract

With the growing importance of the climate objectives it is evident to modernize existing buildings in the prosperous city suburbs. Due to the industrial revolution the cities have grown fast and strongly at the end of the nineteenth century. Many of these buildings demonstrate energy saving opportunities up to 25% by modernizing and renovating. It is a particular challenge to modernize these existing buildings because most of them are historical and under protection order. The paper deals with an example of a typical Berlin tenement. It is shown the modernization from existing standard up to a low energy building. The energy demand is calculated with the German standard DIN V 18599. At last the result is analyzed economically by the facet of Life Cycle Assessment.

Keywords: energy modernization LCC tenement

Streszczenie

Wobec rosnącego znaczenia celów związanych z klimatem oczywista staje się modernizacja budynków stojących na zamożnych przedmieściach. Za sprawą rewolucji przemysłowej pod koniec XIX w. miasta rozwijały się szybko i gwałtownie. Wiele budynków wykazuje potencjał energooszczędności sięgający poziomu 25% przez działania modernizacyjne i renowacyjne. Szczególne wyzwanie stanowi modernizacja obiektów historycznych objętych ochroną prawną. Artykuł wykorzystuje przykład typowej berlińskiej kamienicy czynszowej i przedstawia jej modernizację od poziomu obecnego do standardu budynku niskoenergetycznego. Zapotrzebowanie na energię obliczane jest przy uwzględnieniu niemieckiej normy DIN V 18599. Wyniki analizowane są pod względem ekonomicznym w aspekcie oceny cyklu życiowego.

Słowa kluczowe: energetyczna modernizacja kamienic czynszowych

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1. Introduction

To achieve the climate protection goals of the EU in the prospering European towns, it becomes increasingly important to modernize urban buildings energetically.

Towns which have strongly grown in the course of the industrial revolution at the end of 19th century, have huge energy saving potentials by energetic modernization of tenements from the "Wilhelminian time". In Berlin, for example, are 25% of all apartment buildings tenement houses. [1] We could find this building type in whole Europe, as well in Prague, Budapest, Vienna (called "Zinshaus"), Hamburg (called "Etagenhaus") and Stockholm. According to the regional social needs in the "Wilhelminian time" they are designed differently. But there are also similarities such as the arrangement and the decorative shaping to the street, the existing development, 5 to 6 floors, many residential units, central stairwells, wide corridors and small roof surfaces.

The special challenge by the modernization arises from the small roof surface which is not suitable for Photovoltaic and the conservation of monuments and historic buildings. Thus, for example the buildings in Vienna are included in the UNESCO list of World Heritage Sites. In Germany, their stucco facades are protected as a cultural heritage.

2. Energetic balance of a typical Berlin tenement

The energy requirement is calculated according to German standards for residential buildings based on DIN 18599 with the software program "Dämmwerk" of KERN engineering concepts. In this respect, only the conditioned areas of the considered building are accounted. The cellar and the attic are unheated considered. It turns out a warmth-transferring surface of 2205 m² for the calculation model. The existing building described below should be accounted in comparison to optimized variants to achieve an aimed low energy standard with a defined primary energy demand of $Q_P \leq 40$ kWh / (m²a).

This corresponds to an energy standard much better than what is currently demand in the "Energy Saving Act", which is the actual German standard.

2.1. Description of the existing building as a calculation example

First of all the existing building should be balanced an account. It is a typical Berlin tenement house from the end of the 19^{th} century with five floors with unoccupied cellar and not expanded attic with an eaves height of 18.80 m. The dimensions and the components correspond to a large part of the actual existing tenements in Berlin. The building is built on two sides accordant to a connection building, so that two external walls are not included in the thermal envelope. For the model, which is shown in Fig. 1, arises a typical C-shaped floor plan. The choice of the basic structure of the building of a typical Berlin tenement house is based on the order of the building inspection department at that time. At that time the lowest permissible level of ceiling height was 2.50m. [2] By reason of these regulations no attics have been expanded at the turn of the century. Because of that the uppermost energetically limiting component, the upper floor, is usually a wooden raftered ceiling. The lower end of the thermal envelope forms the "Prussian cap ceiling", because the cellars are usually not heated and these kinds of ceilings were mainly

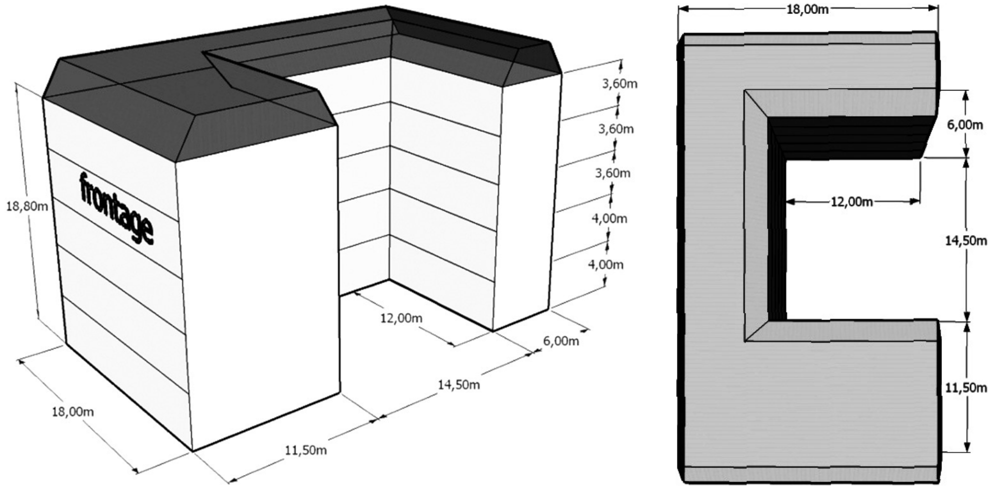

Fig. 1 Building model as a typical tenement

Rys. 1. Model typowej kamienicy czynszowej

used in wet and cool rooms. [2] The outer walls were typically designed in brickwork with lime mortar in the cross bracing. The thickness of the outer walls varies in dependence of their orientation as well as the respective floor number. The street front is usually a preserved-worth stucco facade. The windows show up as wood casement windows with single pane.

The heat transfer coefficients of the external components of the building are shown in Tab. 1.

For the existing building are so far no structural modernization efforts made since the establishment. Only the installation engineering has been modernized so that it no longer exists as it used from remote coal-burning stoves, but out of decentralized floor heating systems based on natural gas. This heating was common in the early 70s.

2.2. Modernization of the structural fabric

The first step of the redevelopment is inevitable the modernization of the external thermal envelope which means that all external components of Tab. 1 are replaced, so that the maximum values of the "Energy Saving Act (EnEV)" in Germany are maintained. This measure is necessary, in each case in order to achieve the desired target values. The street front cannot be redeveloped because of the architectural conservation; there is only a restoration of the plaster and stucco possible.

2.3. Building tightness test

With the modernization of building it absolutely makes sense to arrange an air leakage test (Blower Door test) according to DIN EN 13829. By demonstrating an air change rate of n_{50}=2,0 h^{-1}, a more favorable approach to be taken into account in the calculation and the ventilation heat losses are kept to a minimum.

Table 1

Heat transfer coefficients *U* [W/m²K] of the tenement in comparison to the maximum values of the „Energy saving Act (EnEV)" in Germany

Component	Heat transfer coefficient of the existing building [W/m²K]	Heat transfer coefficient after the modernization [W/m²K]	Maximum values of the EnEV [W/m²K]
External wall with 38cm brickwork	1,46	0,20	0,24
External wall with 51cm brickwork	1,18	0,19	0,24
External wall with 64cm brickwork	1,00	0,19	0,24
Old-style box-type windows	2,80	1,00	1,30
Attic floor	0,96	0,17	0,30
Cellar ceiling	1,56	0,20	0,30

2.4. Modernization of the installation engineering

The following additional restructuring steps are examined and the results are shown in Tab. 2. The above mentioned desired standards can often only be maintained by solar panels, heat pumps or Photovoltaic systems. Normally, a combination of all arrangements with each other make sense or as an addition to the conventional heating system. In each case the pipes have to be insulated and also the radiators with their components have to be renewed. For this a two pipe system is chosen. The central heating is situated in the unheated cellar and it supplies the whole tenement with warm water and heating power. A system of 150m² solar panels on the roof of the building will add warm water to the system. The heating is generated by district heating, which was available in 36 % of cases in Berlin in 2006. [3]

3. Explanation of the optimization

3.1. Optimization steps for a low energy standard

In the following table the different restructuring steps are shown. The calculated results for the primary energy demand and the final energy demand are listed. Supplementary, the percentage of the different final energy uses are also allocated by energy source in Tab. 2. In the first line are the data of the existing building as a basis for a comparison with the other restructuring steps. First you could find data for the modernization of the external components like it is described above. Secondly, in order of the table there are data for the building after the Blower-Door test has been done. Finally, the renewing of the heating and warm water system is the last restructuring step to realize. It is obvious that the energy demand is reduced step by step until the low energy demand of less than $Q_P \leq 40$ kWh / (m²a) is met.

Table 2

Additional restructuring steps and their effect on the annual primary energy demand

Restructuring step	Primary energy demand [kWh/m²·a]	Final energy demand [kWh/m²·a]	Fuel use	electric power use	Solar power use
existing building	214,0	215,0	99 %	1 %	-
Modernization of the external components except the street facade	106,9	107,4	99 %	1 %	-
Building tightness test (n_{50}=2,0 h^{-1})	94,7	95,1	99 %	1 %	-
Renewing of heating and warm water system with district heating and solar panels	37,3	81,7	65 %	3 %	31 %

Fig. 2 demonstrates very clearly that the renewing of the installation engineering has the strongest influence on the primary energy demand. The low energy level has been obtained. At the same time, it is also shown the final energy can be reduced again by 14%. However, the 61% decrease of the primary energy is the result of the convenient energy factor of Berlin district heating of e_p = 0,567. [4]

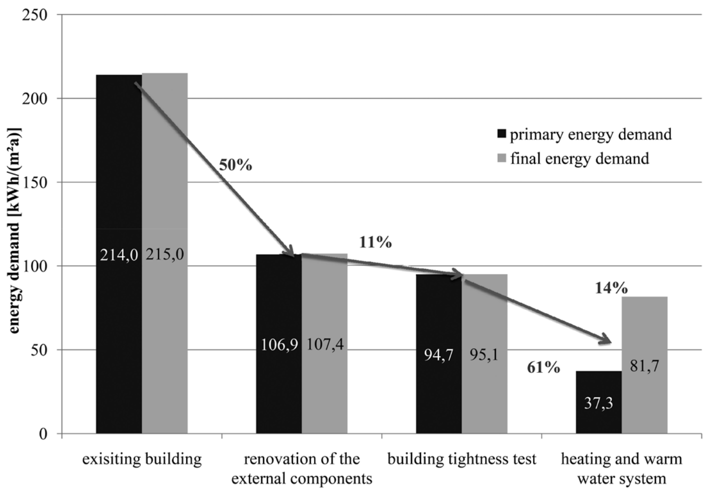

Fig. 2. Restructuring steps

Rys. 2. Etapy restrukturyzacji

3.2. Other optimization possibilities

Because of the different and special needs for the renewing of the heating system as it is described in 3.1 the conditions for developing a low energy standard tenement do not always exist like the roof orientation or the roof area. District heating for tenement buildings is not always available as well. For this reason other optimization possibilities of installation engineering are calculated. The modernization on the building construction itself are not avoidable. Their energy demands are shown in Tab. 3.

Table 3

Alternative installation engineering

Heating and warm water systems	Primary energy demand [kWh/m²·a]	Final energy demand [kWh/m²·a]	Fuel use	Electric power use	solar power use
existing building	214,0	215,0	99 %	1 %	-
gas heating with solar panels	63,9	85,6	67 %	3 %	30 %
Block type heating (CHP)	57,0	77,3	98 %	2 %	-
Central wood pellet-heating	49,0	80,4	98 %	2 %	-
Renewing of heating and solar panels	37,3	81,7	65 %	3 %	31 %

The different variations use mostly different primary energy or fuels. The different heating systems and combinations are in order of the table: a central gas heating in combination with solar panels for hot water, a block type heating (CHP) with gas with cogeneration which produces also electric power and a central wood pellet-heating.

4. Profitability analysis and life cycle costs

All presented variations of energy modernization of the tenement are compared economically by using the software program LEGEP. For this purpose calculates the present value of all reconstruction options. The present value is defined as the time-adjusted cash amount of all costs within a life cycle of 50 years. The costs are discounted to the start of the measure. Considered are the construction costs and the maintenance, repair, operating, fuel and disposal costs. The annual inflation rate is generally 2% and 4% for the fuel. The results of the calculations are shown in Tab. 4 and Fig. 3.

Table 4

Present values of installation engineering

	present value costs in total [€]	present value of fuel consumption [€]
Existing building	1.289.380	1.104.480
Solar panels with district heating	1.032.020	450.410
Central gas heating with added solar panels	809.220	207.880
Central wood pellet-heating system	753.630	428.100
Block type heating (CHP) (with electricity credit)	688.270	343.540

Without including a possible gain in value it is evident that the present value costs in total can be reduced, based on a life cycle of 50 years, on the condition that modernization of the building is desired to achieve an aimed low energy standard. Of course, most cost savings are reached in fuel consumption.

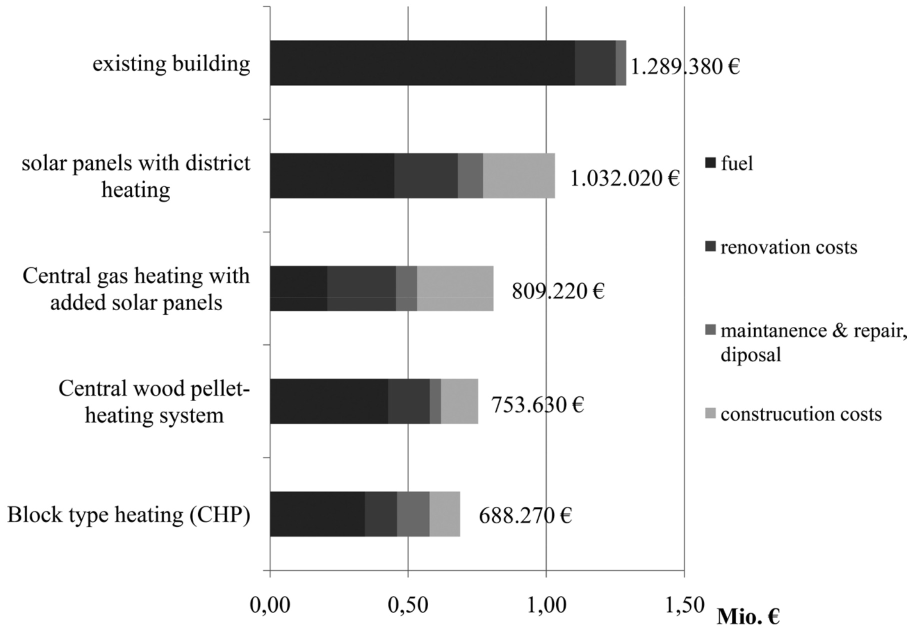

Fig. 3 Present values of the variants

Rys. 3. Obecna wartość wariantów netto

5. Results and discussion

The investigation has shown that tenement buildings can be upgraded to low-energy buildings with the understanding of local, aesthetic, and conditional boundaries. However, it will be difficult over the low-energy house standard of time, to generate the building more energy-saving potentials or energy generation potential. These potentials can be raised for the building itself only with technically complex and physically problematic solutions such as interior insulation or with the task of boundaries such as protection of historic buildings. It will be necessary for further opportunities to integrate the building into an energetic neighbourhood management. Thus, CHP-solutions are energetically reasonable and meaningful. Currently in Berlin from primary energy point of view the operation of an apartment building with heating and solar thermal makes sense. This pays off, that Berlin has plants with combined heat and power generating their energy with a share of renewable resources. However, due to the current market situation, this solution is the most expensive. Currently, it is economically sensible to install a wood pellet or to integrate a CHP with an electricity credit. It is to be expected that the market will move in the next few years, in favor of local and district heating.

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