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CLEMENS DEILMANN, KARIN GRUHLER*

RESIDENTIAL AND COMMERCIAL BUILDINGS IN RURAL AREAS – REFURBISHMENT OR NEW CONSTRUCTION?

MIESZKALNE I HANDLOWE BUDYNKI W TERENIE MIEJSKIM – MODERNIZACJA CZY WZNOSZENIE OD NOWA?

Abstract

The use of the existing building stock instead of demolition and new construction is recognized as part of a sustainability strategy. Preserving the building stock can save natural resources (material), and avoids the building waste that would result from demolition. The objective of the research project was to compare (on the basis of present technologies, energy standards and everyday practice) the maintenance, use, and refurbishment of old houses with those of new buildings. For buildings in rural areas, certain assumptions concerning material, energy, and investment input were made. The investigations for material flow calculations showed that if the existing building, requiring functional reorganization, is in a very bad state, and its energy requirement level – which needs to be upgraded – is low, then maintenance material expenditures are high. Nevertheless, the refurbishment and the maintenance of an existing building is a better solution since the complete or partial use of the building shell saves material inputs, as well as reduces CO_2 emissions resulting from the production of building materials. Analyzing the overall cost and energy balance sheets of old houses in comparison with those of new buildings, it is clear that there will be a break-even point for new construction in 20 to 30 years, depending on the energy price scenario and only for those building needing total refurbishment. If the long-term structural building quality is seen as most important, a new one-family house in relation to the maintenance of existing buildings might be an alternative if old houses are not pushed to good energy performance.

Keywords: *material, energy, costs, rural building categories, maintenance, refurbishment, efficiency*

Streszczenie

Idea użytkowania budynków istniejących zamiast ich rozbiórki i wznoszenia od nowa jest istotną częścią strategii zrównoważonego rozwoju. Zachowanie istniejącej substancji sprzyja oszczędzaniu surowców naturalnych i unikaniu powstawania odpadów podczas rozbiórki budynku. Celem projektu badawczego było porównanie, na bazie współczesnych technologii, standardów energetycznych i codziennej praktyki projektowej, utrzymania, użytkowania i modernizacji starych oraz nowych budynków. Wykazano m.in., że modernizacja i dalsze utrzymanie starych budynków o niskim standardzie jest rozwiązaniem poprawnym, bo całkowite lub częściowe wykorzystanie starej obudowy ogranicza zużycie materiałów i związaną z tym emisję CO_2. Biorąc pod uwagę ogólny bilans kosztów i energii dla budynków starych, poddanych całkowitej modernizacji, i nowych, ten sam wynik jest uzyskiwany po 20–30 latach, w zależności od zmian cen energii. Jeśli więc najważniejsze są aspekty długookresowej jakości konstrukcyjnej obiektu, to nowe obiekty mogą być istotną alternatywą, gdy stare budynki nie są modernizowane do poziomu aktualnych wymagań.

Słowa kluczowe: *materiał, energia, koszty, kategorie budynków wiejskich, utrzymanie, modernizacja, efektywność*

* Graduate engineer Clemens Deilmann, graduate engineer Karin Gruhler, Leibniz-Institute of Regional and Ecological Development, Head of Department of Housing and Ecological Design.

1. Introduction

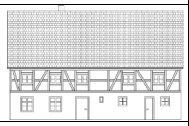
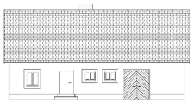
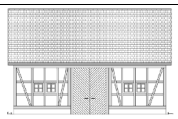
The use of existing building stock, rather than demolition and new construction, is a widely-recognised model for sustainable development. Its justification is seen as being in the saving of the natural resources that would have been used in new construction, and in not having to dispose of building waste and rubble following demolition. A rational economic and ecological use of the building stock, though, must also take account of long--term operating costs. The differing "original states" of the buildings, and their energy consumption levels after rebuilding and refurbishment must likewise be considered. Old buildings, in particular, often require very expensive rebuilding and refurbishment which can equal, or even exceed, the cost of a new building.

The objective of the research project was, on the basis of the information currently available, the relevant specialist literature, and our own research and calculations, to compare the material-, energy-, and cost-related aspects of the re-use and new construction of residential and commercial buildings in rural areas, and to determine the conditions under which the use of existing stock is more economic than demolition and rebuilding.

To approach this problem three common building types were defined – the **farmhouse--stable**, the **house** of the so-called **new farmers**, and the **barn**. These three categories come closest to represent the general shapes of such buildings, their modes of construction as well as locally available materials are shown in Table 1.

Table 1

Home types

	Farmhouse--stable	New farmer's house	Barn	Newly-built house
Elevation				
Built	Pre-1840	1950	Pre-1840	2005
Length/width	15.00 m/8.00 m	16.00 m/8.50 m	14.00 m/7.50 m	10.00 m/8.50 m
Large floors	2	1	1	1
Roof	Gable roof, unconverted	Gable roof, Part-converted	Gable roof, unconverted	Gable roof, converted
Cellar	No cellar	Cellar under part	No cellar	Cellar under entire house
Outer walls	Quarry stone Half-timbered	Quarry stone (base) Brick	Quarry stone (base) Half-timbered	Sand-lime brick

It was necessary to define "artificial", synthetic building types because of the different possible combinations of refurbishment and energy requirements. The material, energy, and cost calculations have been made on the basis of these synthetic building types. Figure 1 shows the method used.

Furthermore, the assumptions on which the material-, energy-, and cost-related calculations are made had to be defined. Generally, the IOER distinguishes between three initial states reflecting the present condition of a building. As varieties of refurbishment three different energy levels were assumed. Since this survey focussed on the building shell

and the necessary building work, a standard energy carrier mix was assumed for all types of a building and refurbishment variety in order to avoid further variations by energy supply. The cost calculations cover a period of 30 years, and take different energy price increases into account (Tab. 2).

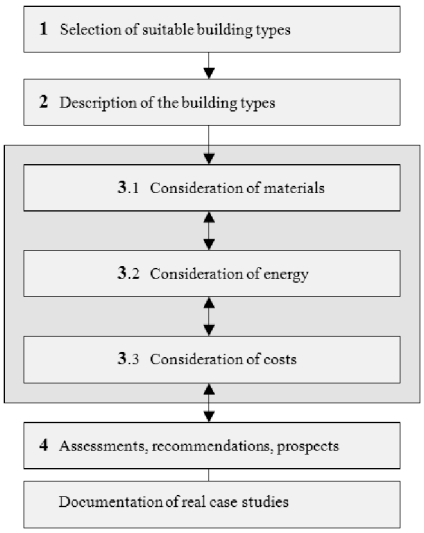


Fig. 1. Approach – schematic outline of the different steps
Rys. 1. Schematyczny opis poszczególnych kroków

Table 2

Basic assumptions made when considering materials, energy, and costs

	Farmhouse-stable, new farmer's house, barn		
Initial condition of building	Condition **A**: 50% of the building intact, unoccupied for about 15 years → **Total** refurbishment	Condition **B**: Structure of building largely satisfactory, unoccupied for 2–5 years	Condition **C**: Building fairly well maintained, occupied → **Normal** refurbishment
Energy saving levels	**Low** energy requirement (Low ER): Energy-saving regulations – requirements for **building stock**	**Normal** energy requirement (Normal ER): Energy-saving regulations – requirements for **new buildings**	**High** energy requirement (High ER): Low-energy consumption house standard
Energy carrier mix	**50%** heating oil, **30%** heat pump, **15%** coal, **5%** natural gas		
Energy price increases	**Variety 1:** **0.6%** annual increase on the basis of an energy carrier mix	**Variety 2:** **3%** annual increase on the basis of an energy carrier mix	**Variety 3:** **8%** annual increase on the basis of an energy carrier mix

2. Material-, energy-, and cost-related analyses and comparisons

2.1. Consideration of materials (material balance sheet)

The refurbishment of existing buildings involves inputs and outputs of materials. Building materials or elements that are damaged, or no longer required by the concept, must be removed and disposed of, while new materials and elements needed for refurbishment are then installed. When refurbishing the standard building types the material outputs range, depending on the original condition, from 0.23 to 0.79 t/m² 79 t/m effective (mainly used) area.

The older farmhouse-stable type of buildings have relatively high material outputs (on average 0.64 t/m² effective area), which means that on average, only 65% of the built volume can be re-used. The new farmer's house, a building type that is significantly newer than the farmhouse-stable type, and so in a better condition, has roughly only half this output (on average 0.33 t/m² effective area); here a good 80% of the built volume can be re-used.

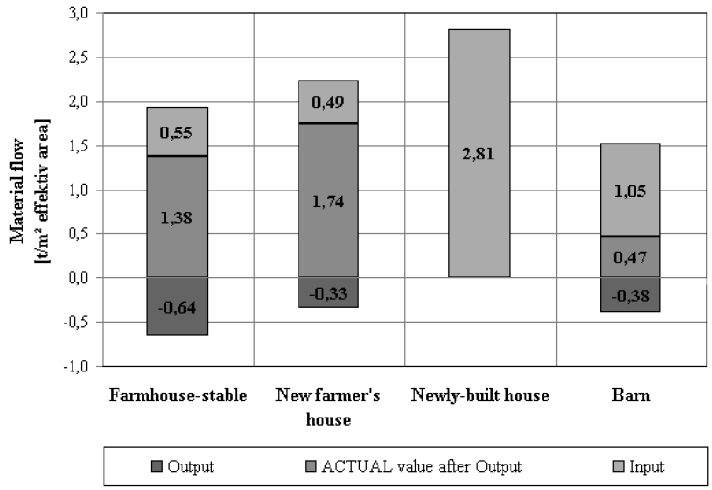


Fig. 2. Average material flows for refurbishment, rebuilding, and new building – comparison of building types

Rys. 2. Zużycie materiałów podczas renowacji, odbudowy i na wzniesienie nowego budynku – porównanie w zależności od typu budynku

Refurbishment and rebuilding thus show clear advantages as compared with new construction. The existing shell can either be partially or completely re-used, or continue to be used. This means a general saving of building materials, as well as avoiding the emissions (including CO_2 emissions) caused by their production.

Also, the quantities of refurbishment material inputs needed for rehabilitating a built volume are far lower than those of the material needed for a new building. Refurbishing a farmhouse-stable requires only 20% of the building materials that are built into a new single-family house; a new farmer's house requires on average only 17%.

Surveys of the material balance sheets have shown that as a rule that the worse the original condition of the building, and the higher the energy-saving level that can be achieved by refurbishment, the greater the amount of material required. Therefore, before older buildings that are in a poor state are refurbished, consideration must be given to whether there is any point in refurbishing them.

Because of their use for a commercial purpose (storage), barns cannot be directly compared with residential buildings. Converting an unheated storage barn into a building that can be used for commercial purposes (such as a workshop) involves a material flow of 1.1 t/m^2 effective area, and is thus more costly from the point of view of the quantities of material involved than the refurbishment of residential buildings, and whoever decides to convert a barn must be aware of this.

2.2. Consideration of energy (energy balance sheet)

The energy-related refurbishment of the building types can result in potential annual primary energy savings ranging from 174 to 260 kWh/(m^2·BGF·a). BGF here stands for gross floor area. Compared with the original state these are savings of between 55 and 70%. That means that the energy requirements of both the farmhouse-stable and the new farmer's house can be reduced to about one third of those when in their original states (Tab. 3).

Table 3

Annual primary energy requirement for the different building types and a newly-built (modern) house

Annual primary energy requirement, as kWh/(m²·BGF·a)	Building stock	Refurbishment and newly-built house		
	original state 20°C	low energy requirement	normal energy requirement	high energy requirement
Farmhouse-stable	356 (100%)	151 (42%)	122 (34%)	96 (27%)
New farmer's house	317 (100%)	143 (45%)	113 (36%)	96 (30%)
Newly-built house			119	

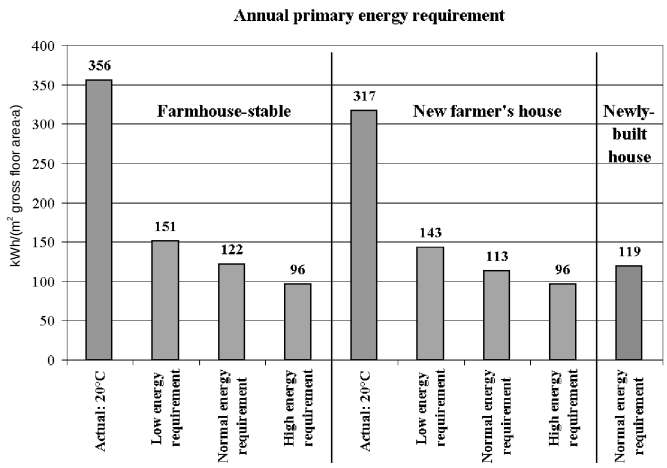


Fig. 3. Annual primary energy requirement of building types with a new single--family modern house

Rys. 3. Porównanie zapotrzebowania na energię różnych typów budynków i nowoczesnego budynku jednorodzinnego

As a rule, the refurbishment of existing houses in rural areas can achieve the energy requirement of a new house (normal energy requirement). But in practice, refurbishment to a lower energy requirement will be more relevant. If the building types – the farmhouse--stable, or the new farmer's house – are refurbished to low energy requirement then their annual primary energy requirement is between 20 and 25% higher than that of a new single--family house (Fig. 3).

The new farmer's house reaches this energy-saving level with low material flows (inputs and outputs). Because it is usually not as old as the farmhouse-stable, its original condition is generally better. From the structural and constructive point of view, too, it is better-suited for energy refurbishment. The building shell's geometry is clear and less complicated, and since the exterior walls are homogeneous (not half-timbered), it is easier to "wrap" them in insulation.

Logically enough, when CO_2 emissions are analysed, the results lead to similar conclusions (not shown). Refurbishments of both building types result in CO_2 reductions of about 60% as compared with the original condition.

2.3. Consideration of cost (cost balance sheet)

In drawing up the cost balance, the one-off investment costs for refurbishment and new building, the reserves for maintenance, and the continuous costs for heating and hot water are dealt with as a compound. One should not be surprised by the fact that more effort put into building work to improve functions and comfort also results in a higher one-off refurbishment cost. In fact, the worse the original condition, and the higher the targeted energy-saving level, the higher the refurbishment cost. This is particularly clear in case of the farmhouse-stable (Fig. 4). If the building to be refurbished is in a very poor structural state, the cost of bringing it back into operability is almost twice as high as that of a normal refurbishment (left-hand, blue bars), while the cost of achieving higher energy-saving standards play a relatively minor role.

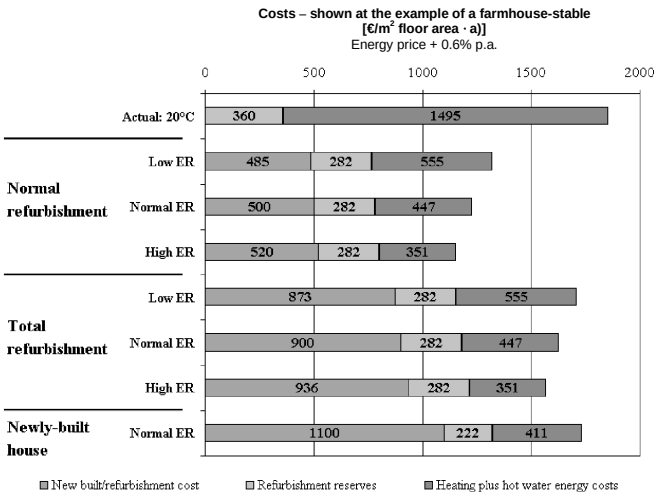
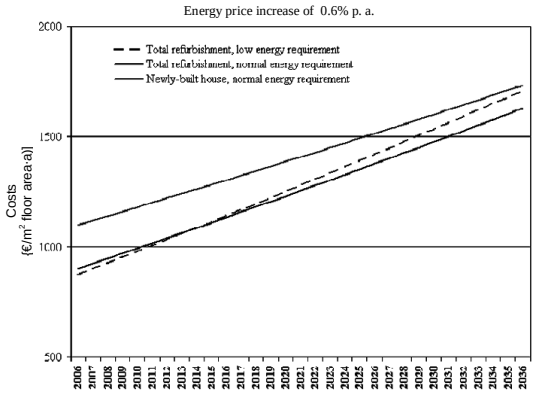


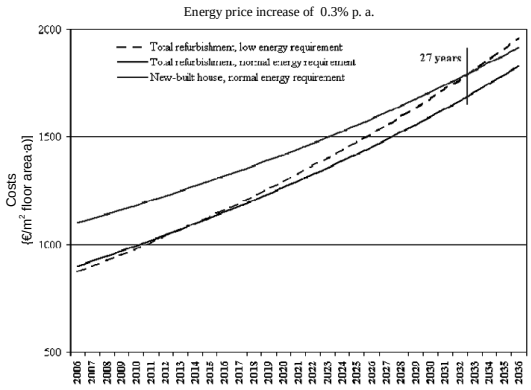
Fig. 4. Farmhouse-stable: 30-year cost balance sheet
Rys. 4. Wiejska stajnia: zestawienie kosztów za 30 lat

The recurring energy costs for heating and hot water (red, right-hand bars) depend on the energy-saving level of the refurbishment. The investments made during refurbishment are amortised in the future as the building is used. Savings of about 65 to 75% of the energy

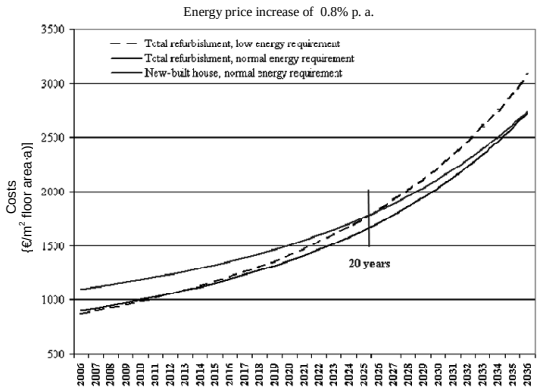


scenarios of energy price increases
(costs = new building/refurbishment costs + reserves for maintenance + cost of energy for heating and hot water)

<u>0.6% p.a.:</u>
New building is only more economic than total refurbishment, low energy requirement after more than 30 years. Cost balance sheets for variable assumed.



<u>3.0% p.a.:</u>
New building is more economic than total refurbishment, normal energy requirement after 27 years.



<u>8% p.a.:</u>
New building is more economic than total refurbishment, low energy requirement, after 20 years, and more economic than total refurbishment, normal energy requirement, after 31 years.

Fig. 5. Farmhouse-stable – accumulated costs based on various rates of price increase
Rys. 5. Wiejska stajnia – koszty zakumulowane na bazie różnych prognoz wzrostu cen

costs for heating and hot water can be made as compared with the initial condition (Actual: 20°C). In particular, refurbishment to achieve a normal energy requirement (Normal ER) allows savings of 70%, but compared with a new single-family house (Normal ES) it is 10% more cost-intensive. The refurbishment of a farmhouse-stable to a high energy requirement (High ER) would be 15% less expensive than the new-built house but seems to be, in practice, difficult to realise.

In total (all the bars) the normal refurbishments, which are based on the structural condition still being good (normal refurbishment), are all more economic than a new single--family house. The total refurbishments, though, show hardly any advantage when compared with the new house. If the assumption is that refurbishments, in fact, comply with the minimum requirements of the current energy conservation ordinance, then the totally--refurbished old building (total refurbishment) does not offer any cost advantage over the new single-family house during the considered 30-year period. This becomes clearer when higher price increases are assumed than those given in the fundamental assumptions (0.6% per annum; Fig. 5).

When one makes an assumption that an average energy price increase will, at 0.6% per year, be moderate, the total refurbishment of the farmhouse-stable building must be seen as an acceptable alternative to a new one-family house. The accumulated costs remain below those for the new building for the next 30 years. If though, a scenario is calculated assuming an annual energy price increase of 3% a year, then after 27 years the new building is, in spite of the higher one-off initial investment cost, more economic than the total refurbishment at a low energy requirement. If the energy price increase does not exceed 8%, the new building becomes more economic even sooner: after only 20 years the investment pays for itself.

The cumulative investigations have also confirmed that the investments aiming at the improvement of the building energy-saving quality are amortised after only a few years. Thus in case of normal refurbishment of a farmhouse-stable, the qualitatively higher energy-saving variety will have paid for itself in 5 years, while the economy of total refurbishment outperforms that of the basic variant after 8 years. For the new farmer's house the figures are similar.

3. Final conclusions

When materials are being considered, there are clear advantages in refurbishing existing buildings in rural areas when compared with new construction. Depending on the initial state of the building, most of the existing built volume can be re-used or continue in use – in the buildings surveyed here, between 65 and 80%. Thus, new building materials are saved, and the emissions (including CO_2 emissions) arising from their production are reduced. As a rule, only 15 to 20% of the amount of new materials that would have been required for a new construction is needed in case of rehabilitation. The worse the initial condition of a house, and the higher the energy-saving level aimed at, the greater the quantity of the material required for the refurbishment. Therefore, before old buildings in poor condition are refurbished, it should be recalculated whether their refurbishment is really justified.

When refurbishing existing houses in rural areas, it is generally possible to achieve the energy performance specified by energy conservation regulations for a new one-family

house (Normal ER). Yet, everyday practice shows that the values for new buildings given in legislative regulations are rarely met. On the one hand, the requirements for existing building stock listed in the regulations bear the opportunity to exceed the parameters set for new buildings. On the other hand, stringent rules for the preservation of historic buildings often foil such attempts. More practically relevant, therefore, are refurbishments to a low energy requirement (Low ER). If existing buildings are refurbished to this standard, then their annual primary energy requirement is 20 to 25% above that of a new one-family house.

In terms of costs it is also true that the worse the original structural state of the building, and the higher the energy-saving level to be met, the higher the refurbishment costs. If the building being refurbished is in a poor structural condition, the investment required to make it operable again (total refurbishment) almost doubles that for a normal refurbishment (normal refurbishment).

Compared with a new one-family house, normal refurbishments which assume that the original state of the building is still good, are less expensive in their entirety, while the total refurbishments hardly show any cost advantage as compared with the new construction. If total refurbishments improve energy-saving values merely to the basic level, such refurbishments offer no real alternative to new construction so far as long-term (30 years) costs are concerned. This becomes even more apparent when energy prices increase.

To sum up, it can be stated that high-quality (exceeding the energy-saving level required at present) refurbishments are good long-term investments (new built/refurbishment costs, refurbishment reserves, heating plus hot water energy cots). For those buildings in need of total refurbishment it is a must, otherwise new construction – considering all the primary energy content of the building materials – will be more economic. For houses in reasonable state, refurbishment which reduce energy demand by 50% will in general be more economic for 30 years than new construction.

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