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Energy and economical evaluation of residential buildings in Slovakia

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Abstract. The main objective of the research is to make evaluation of energy and economic by the retrofitting of the residential buildings. If this methodology can be an appropriate tool to guide decisions related with the building energy performances and to identify the most cost-effective variants of the renovation, that could be applied to the building stock in Slovakia by the analysis of the life-cycle costs of the representative apartment buildings.

The specific objectives of this study were the following:

- Theoretical analysis of the residential buildings stock in Slovakia
- Analysis of the studied residential buildings and their energy parameters before and after renovation
- Simulation of the energy performance of the apartment buildings
- Mathematical modeling of the technical and economic parameters

1 Intorduction

The building sector in the EU is responsible for about 40% of the global energy consumption and up to 36 % of the total carbon dioxide emissions. In order to reduce energy consumption and promote energy efficiency of buildings, the EU Member States have to set cost-optimal levels of energy performance criteria in their regulations that became a national priority across the EU [1]. As the reduction of energy consumption is to a large extent associated with the renovation of the old housing stock that represent a great challenge when in particular financing of the necessary investments to energy saving measures poses the biggest barrier [2]. Although the housing stock in Slovakia belongs to youngest in Europe, built from 1948 to 1990 [3], the residential buildings built by mass forms of construction have been in use for several decades and the limitations associated with the excess of the planned lifetime of the building structures and technical systems are becoming apparent [4].

A significant proportion of these existing buildings does not fulfil the current European requirements on the energy efficiency [5]. The main legislation is the European Directive 2010/31/EU [1] that requires each state to implement suitable policies to improve the energy efficiency of the existing buildings, until new buildings have almost zero energy consumption by 2020, to hit long term energy and climate targets. Energy efficiency has to be increased at all stages of the energy chain, from the generation to the final energy consumption. At the same time, the benefits of increased energy efficiency must outweigh the investment costs of building renovation. Adding thermal insulation to the building envelope and replacing the old glazed windows with new more energy efficient ones significantly reduce the energy consumption of building and may also improve the thermal comfort [6].

The study investigated three pairs of the residential buildings before and after their renovation. The simulation of the energy performance of different renovation alternatives were carried out to determine the energy consumption of the apartment buildings with different variants of the renovation.

The article investigates the energy efficiency, economic viability and also investment costs of energy renovation of existing apartment buildings. The real energy uses of the apartment buildings were measured to determine the actual state before the complex renovation. The individual energy efficiency measures and the renovation variants were composed for the representative apartment buildings in order to analyse cost-effective energy efficiency levels and the investment costs for building renovation.

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2 Retrofitting of existing building stock

The construction sector is still expanding, which is bound to increase its energy consumption. In order to reduce the growing energy expenditure, the European Directive imposes the adoption of measures to improve the energy efficiency in buildings [7]. The European Union (EU) provides it's Member States with a long-term framework for dealing with the issue of sustainability and reduction of energy consumption to gain the buildings with almost zero energy consumption. The European Commission recently proposed the Europe 2020 flagship initiative for reaching resources efficiency in Europe and within this framework it is now putting forward a series of longterm policy plans in areas such as transport, energy and climate change [7, 8, 9].

The energy consumption of building sector is directly related to CO_2 emissions; account for around 36% of total emissions in Europe. Moreover, CO_2 emissions are directly connected to the particular energy mix used in existing buildings in a particular EU country [7, 11]. Energy in European buildings is mainly consumed by space heating, cooling, hot water preparation, cooking and equipment, where the biggest consumer is space heating [12]. The energy performance of the existing buildings depends on thermal efficiency of the building's exterior constructions, efficiency of the supply system, climatic conditions and also the behavior of the users.

The existing buildings are very important to reach the EU's energy saving targets and to struggle climate change whilst contributing to energy security. The EU's Energy Performance of Buildings Directive (EPBD), is the main legislation instrument for improving the energy performance of our existing old building stock [15].

The energy efficiency measures in building renovation represent an opportunity to improve the energy efficiency of buildings. The challenge for existing buildings is to "unlock" that vast potential and realize the cost-effective benefits of a built environment [13]. Despite the fact the retrofit of existing buildings offers such a high potential in terms of energy savings, there are many barriers why investments into renovation measures in buildings are often refused or just partially realized. The main barriers are based on the financial factors, lack of knowledge (awareness), separation of investment costs and benefits, administrative factors, lack of installers and "know how", information and technical expertise [7, 14].

In Slovakia, there are number of national programs, strategies and action plans aiming to achieve the 2020 targets. Many of them are primarily focusing at improving the energy performance of buildings and the use of renewable energy sources in buildings. Renovation of existing buildings is the key task formulated to contribute to reaching 2020 goals. The thermal performance requirements for buildings are stricter, establishing thus a precondition for effective thermal protection of buildings needed to comply with the requirement for reduction of energy consumption for heating of existing buildings. Revised standard STN 73 0540-2/Z1, adjusting requirements for individual energy levels of buildings (ultra-low energy demand, almost zero energy demand).

3 Methodology

The methodology used in this study was oriented to the detailed description of the energy saving renovation alternatives that will be the most probably used in the majority of the buildings renovated in Slovakia. The accuracy of the energy modeling in the building stock was intentionally compromised, so that a very limited number of the reference buildings were used considered enough for the estimation of the technical energy saving potential.

3.1 Objectives of the study

The main objective of the research is to evaluate the life cycle cost analysis, if this methodology can be an appropriate tool to guide decisions related with the building energy performances and to identify the most cost-effective variants of the renovation, that could be applied to the building stock in Slovakia by the analysis of the life-cycle costs of the representative apartment buildings.

- Theoretical analysis of the residential buildings stock in Slovakia
- Analysis of the studied residential buildings and their energy parameters before and after renovation
- Simulation of the energy performance of the apartment buildings
- Mathematical modeling of the technical and economic parameters

3.2 Description of the studied apartment buildings

The chosen buildings are typical representatives of different groups of existing building stock in Slovakia. They represent 87% of the existing building stock based on the total floor area.

Table 1: Description of studied apartment buildings

Building	I	II	III
Construction system	T, brick masonryP100 from burnt bricks	P.1.14	P.1.14
Year of construction	1954	1983	1992
Number of floors	6 ground floors 1 underground floor	13 ground floors	8 ground floors
Number of apartments	36 apartments	48 apartments	14 apartments
Area (m²)	2 089	4 290	1 223
Volume (m³)	6 268	12 012	3 425
View of building before renovation			
View of building after renovation			

4 Results

4.1 Energy evaluation

The energy evaluation consists of two parts. The first method was focused on the calculation of energy demand. This method was based on the Slovak national standards and the building code to classify apartment buildings into energy classes. The calculation methods for the evaluation of the annual heat demand for the space heating are specified in STN EN ISO 13790 . The second method was focused on the energy performance evaluation. The evaluation was based on the real energy consumption of the apartment buildings before and after the renovation. The measured data of the real energy consumption were provided by the appropriate housing association companies, for three and five years (Building I 2012-2016, B.II 2009-2011, B.III 2011-2015).

The measures focus on a building envelope improving, the heating system and the domestic hot water system efficiency improving. In order to improve the energy efficiency of the existing buildings, the most significant options are applications of all energy saving measures at once = complex renovation of the building. The series of variants were developed to apply to the building constructions to determine the applicable and reasonable one. Another group of measures was applied to the building services.

Table 2: The calculated energy demand and the classification into energy classes

Building		**Energy demand for space heating**		**Potential savings**	**Energy class**	**Energy consumption for space heating**		**Real energy savings**
		(kWh/year)	**(kWh/m². year)**	**(%)**		**(kWh/year)**	**(kWh/m². year)**	**(%)**
I	Original	307 323	147	49.8	F	258 861	124	41
	Renovated	159 699	76		C	154 608	74	
II	Original	418 059	98	50.5	D	358 017	84	42
	Renovated	214 581	50		B	209 278	49	
III	Original	110 920	91	40.1	D	97 141	79	40
	Renovated	69 189	57		C	258 861	124	

The results show that the renovation of the buildings can bring significant savings, more than 40% compared to the buildings in original condition.

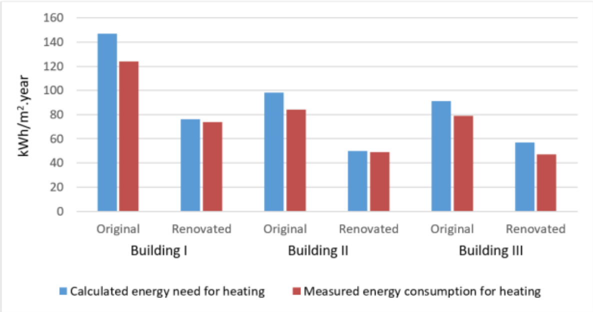

Fig. 1. The comparison of the measured heat consumption and the calculated energy demand for the space heating in the residential buildings before and after the renovation

4.2 Economical evaluation

Taken into account the individual needs of the owner, including affordability, and as much as possible, finding a balance between what is technically feasible and what the owners/ investors want. First part of the evaluation is focused on the technical part of the renovation and second is focused on the economic evaluation through parameters such as: investments, annual savings, economic lifespan of constructions, the discount rate and the interest rate influenced by the source of the funding.

A financial analysis was developed for the investor, which clearly shows the time in which the investment is paid off and when it starts to be profitable. Because the cash flow depends on a large extend on the method of financing of the project, several options for financing the project were developed. In the next figures is the most profitable distribution of the financial resources for the renovation of evaluated buildings.

Table 3: The distribution of the financial resources for the renovation – SHDF and Bank

Financial resources	Share of the total costs (%)	Building I Investments (EUR)	Building II Investments (EUR)	Building III Investments (EUR)	The interest rate (%)	Term (years)
Loan from the Fund (SHDF)*	75	99 000	213 500	72 500	1	20
Loan from the Bank	15	20 000	41 000	14 400	3.9	25
Own capital	10	14 100	28 125	9 178	-	-
Total costs	100	133 100	282 625	96 078	-	-

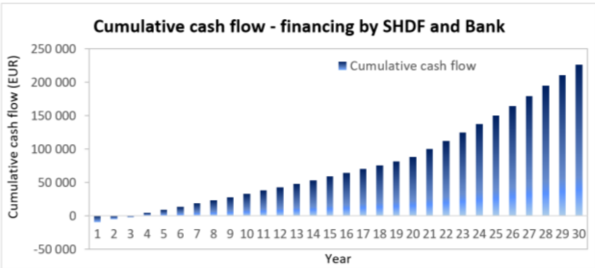

Fig. 2. Cumulative cash flow of Building I renovation, financing by SHDF and Bank

With the combined financing from the SHDF and Bank, in the Building I, it takes 4 years to get back the money invested into the renovation. After that period there is just the profit from the investment.

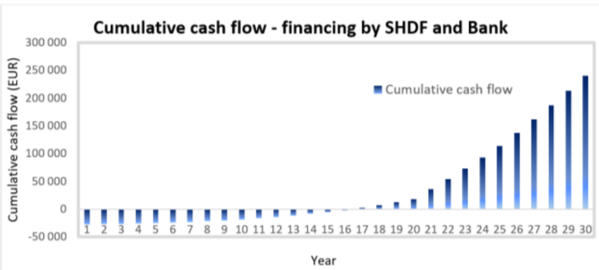

Fig. 3. Cumulative cash flow of Building I renovation, financing by SHDF and Bank

With the combined financing from the SHDF and Bank, in the Building II, it takes 17 years to get back the money invested into the renovation. After that period is just the profit from the investment.

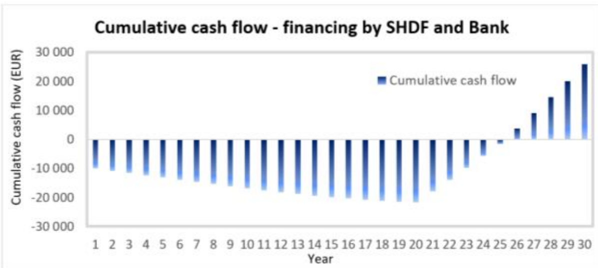

Fig. 4. Cumulative cash flow of Building I renovation, financing by SHDF and Bank

With the combined financing from the SHDF and Bank, in the Building III, it takes 26 years to get back the money invested into the renovation. After that period there is just the profit from the investment.

5 Discussion

The results of the cumulative cash flow analysis with the combined financing from the State Housing Development Fund and the Bank showed that, in the Building I, it takes 4 years to get back money invested into the renovation, in the Building II, it takes 17 years and, in the Building III, it takes 26 years. After that period, the investment starts to be profitable. The complex renovation of the Building III is not profitable, because money is not returned after the estimated life time. After that period, it is necessary to provide another investment. In this case it is better to provide just partial renovation of the building.

6 Conclusion

This thesis presented the experimental investigation of the impact of the building renovation on the energy consumption of the studied apartment buildings. The main findings of this study reveal that in the current case the existing buildings could be renovated to meet the energy-efficiency levels as new buildings. The study confirmed that the energy performance of the existing apartment buildings after the renovation has been improved and the total energy demand could be improved at least by one energy category (according to Regulation 364/2012). The usage of primary energy consumption after the renovation could by improved by 61% on average. The demolition of the existing buildings and the constructing new building has higher environmental impact and increases the life cycle costs compared to the renovation of the existing buildings.

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