IMPROVEMENT OF ENERGY EFFICIENCY OF BUILDINGS IN URBAN AREAS

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Summary: *Although there are a large number of buildings with high energy consumption in Serbia, there is a possibility to reduce it by investing in renovation of such buildings. Windows and doors, which are part of thermal envelope of building, play a very important role in the overall energy efficiency of the building. In this paper, some aspects of reducing energy consumption of buildings in urban area are presented through renovation project and experimental measurements. The results of increased energy efficiency of one public building, obtained by changing doors and windows only, are given. Experimental measurements by thermovision camera in several residential buildings are shown in this paper. These measurements indicate importance of installing adequate windows as part of thermal envelope of buildings. In addition, corresponding data, from overall state of energy efficiency of buildings in Serbia, is presented.*

Keywords: *energy efficiency of buildings, renovation, mesurements*

1. INTRODUCTION

In order to improve current state of energy efficiency of buildings, Republic of Serbia adopted new regulations based on the Low of planning and construction (official gazette No. 72/2009, 64/2010). This regulations [1] are based on European Directives (EPBD 2002 and EPBD 2010-Recast) [2]and they oblige all member states to introduce Passport of energy efficiency (hereafter will be referred as Passport of EE) for houses. Without Passport of EE new buildings can not obtain permission for usage, while already existing buildings can not be sold or rented.

It is well known that existing buildings often have low level of energy efficiency. However, there is a high potential for cost-effective energy savings in building sector in whole Europe. Renovation programs which targeted improvement of energy performance of multi-apartment buildings in Central and Eastern European countries have been started, and a number of buildings (both, municipal and privately owned) are

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retrofitted already. Resulting savings in heating energy consumption mainly range from 30 to 50% [3]. Unfortunately, in Serbia such programs are still at an early stage.
In this study it is shown that considerable savings can be achieved if the buildings are properly repaired according to the principles of energy efficiency. In order to realize renovation projects on a larger scale in Serbia, there are numerous conditions that need to be fulfilled such as: developing measures and tools triggering an improvement of the construction quality in renovation projects in countries; developing coherent decision making and business models reflecting regulatory, economic, social and technological aspects in energy efficient renovation of multi-apartment buildings, etc. [3].

2. STATE OF ENERGY EFFICIENCY OF BUILDINGS IN SERBIA

Reducing energy consumption and eliminating energy wasting should be among the main goals of our and other European countries. In developed countries, the global contribution to the energy consumption of buildings, both residential and commercial, is between 20% and 40%. According to official data [4] in Republic of Serbia energy consumption in buildings is 38%, while in industry and traffic is 34% and 28% respectively. According to these data, it is clear that buildings sector provides significant opportunities for energy savings. As an illustration of this fact, some of the data obtained in performed research [5], [6] are presented. It was found that heating accounts for 61% of energy consumption are for buildings. Therefore, most energy saving potential is associated with increased use of thermal insulation, which should reduce heat losses. Data gathered from the mentioned analyzes shows that in residential sector, most of the building stock is over 30 years old. The average heat consumption in buildings in our country is about 160 kWh/m^2, which is much higher when compared to corresponding values in European Union countries which are 70-130 kWh/m^2. This indicates that there is opportunity for a substantial energy efficiency improvement of building stock in Republic of Serbia. Also, recently implemented projects for improvement of energy efficiency of public buildings, mainly schools and hospitals, indicate that potential savings are in the order of 30%- 40% with attractive payback periods [7].

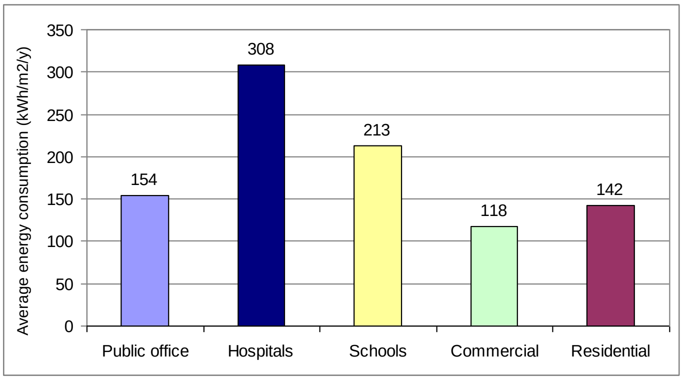

Figure 1: Specific energy consumption for different building types (summarized)

Figure 1 shows consolidated data for specific energy consumption for different building types. It can be seen that energy consumption in both public and residential buildings is very high. Calculation methodology of energy saving potential and assessment of needed investments can be found in [5], [6], [8]. In this paper only the average annual energy savings in kWh/m2/y are given, and energy savings as a percentage of the actual energy consumption (Figure 2). It can be concluded that greater potential for energy savings is observed in public buildings when compared to the residential buildings.

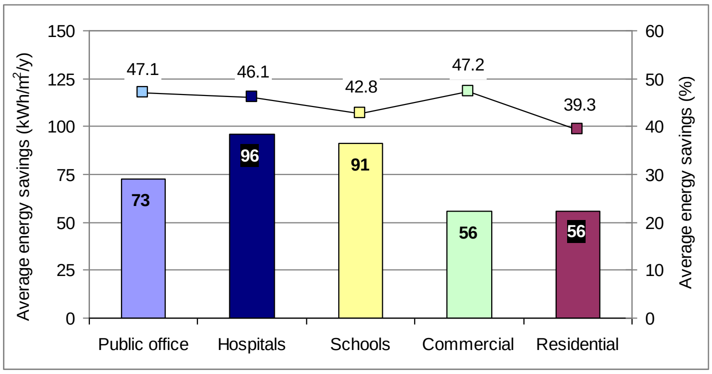

Figure 2: Average energy savings per building sector (summarized)

3. REDUCTION OF ENERGY CONSUMPTION AND POTENTIAL SAVINGS

Considerable reduction of energy consumption of buildings in urban area can be achieved by reconstruction of their thermal envelope. Results of renovation project of one public building (Figure 3) are presented in this analysis. Retrofitting of the building included replacement windows and external doors. Corresponding cost analysis and conclusions are given.

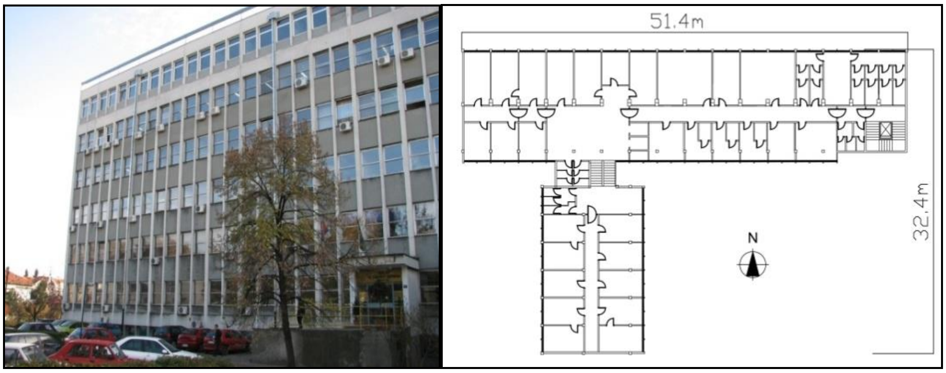

Figure 3: The Façade and the basis of third floor of the analyzed public building

Deterioration of windows causes higher energy consumption (and higher bills) and also represent threat to safety of people. That is the reason why it was necessary to make the main project of replacing the existing windows on the façades of the Institute of Public Health of Vojvodina in Novi Sad. The project included replacing of existing windows, entrance portals and skylights with plastic-aluminum windows. The project also predicted treatment of damage caused by such replacements and also other work. It was concluded that there are 320 of elements that needs replacement and cost represented by different phases of project is presented in Table 1.
Based on the project of renovation, corresponding analysis of energy savings is presented, where calculation is based on the current energy efficiency regulations. Since only one part of thermal layer (windows and doors) is changed, difference in energy needed for heating in old and new (renovated) thermal layer is presented. That difference reflects in both energy losses and energy gains caused by installing new elements in thermal layer. In this calculation, it is adopted that all considered elements are part of thermal layer.

Table 1. Estimation of renovation works cost (rsd)

1.	Preparation work and dismantling		666.712,04
2.	Procurement and installation of new windows and doors		18.872.742,28
3.	Repairs after installation		1.538.674,91
4.	Procurement and installation of drip benches		1.167.683,00
5.	Dismantling and installation of air conditioners		356.250,00
		Total:	22.602.062,23
		Taxes:	4.068.371,20
		Sum:	26.670.433,43

Based on the dimensions of new and old elements, calculation is performed according to following expressions:

$$Q_{H,nd}^{dif} = Q_{H,ht}^{dif} - \eta_{H,gn} \cdot Q_{H,gn}^{dif} \quad \text{[kWh/a]} \tag{1}$$

where $Q^{dif}_{H,nd}$ is difference in annual energy needed for heating before and after the renovation. Since renovation consisted of changing of doors and windows only, in expression **(1)** are taken into account only members that relate to those elements of thermal envelope.
$Q^{dif}_{H,ht}$ is calculated as corresponding difference in annual needed energy for compensation of energy loss that account both transmission and volume losses. $Q^{dif}_{H,gn}$ is also difference, but in heat gains, that for corresponding calculation included only solar gains. Quantities of energy before and after renovation are calculated according to the

same expressions, but for different values of coefficients for old and new elements according to current EE regulation in Serbia.

$$Q_{H,ht} = (H_{TS} + H_V) \cdot HDD \cdot 24 \cdot 10^{-3} \quad \text{[kWh/a]} \tag{2}$$

$$Q_{H,gn} = Q_{sol} = F_{sh} \cdot A_{sol} \cdot I_{sol} \cdot \tau_{sol} \quad \text{[kWh/a]} \tag{3}$$

Difference in annual energy needed for heating obtained by measures of renovation according to performed calculation is 250275 kWh. Repayment period for renovation cost depends on market price of kWh, and it is presented in Figure 4.

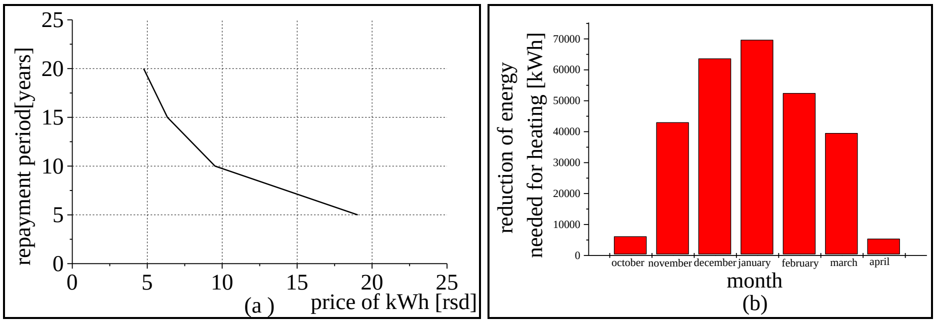

Figure 4: Estimates based on performed calculation: (a) Repayment period vs price of kWh; (b) Energy savings per month annually.

Since calculation of reduction of energy consumption in public building is based on regulations, it can be said that determined savings are only estimate. It is clear that for more realistic analysis correlation with experimental measurements are needed.

4. EXPERIMENTAL MEASUREMENTS AND OBSERVATIONS

Use of thermovision camera has an important role in the assessment of energy losses in residential and public buildings. Heat losses and temperature variations of the building envelope can be detected using the obtained images. Detecting and correcting identified irregularities can greatly improve the energy efficiency of the building.
In order to emphasize importance of quality exterior windows and doors, the results of such research [9] are presented. The aim of this project [9] was to determine potential energy savings that can be obtained by retrofitting and improvement of the thermal envelope of buildings in urban area. Some of the characteristic results of performed measurements are given in Figures 5 and 6.

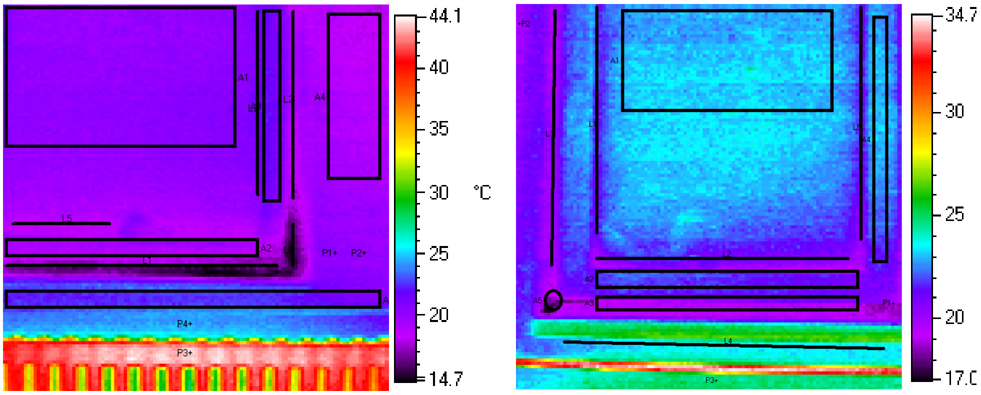

Figure 5: Images obtained by thermovision camera on window of observed residential building: (a) old window, (b) new window

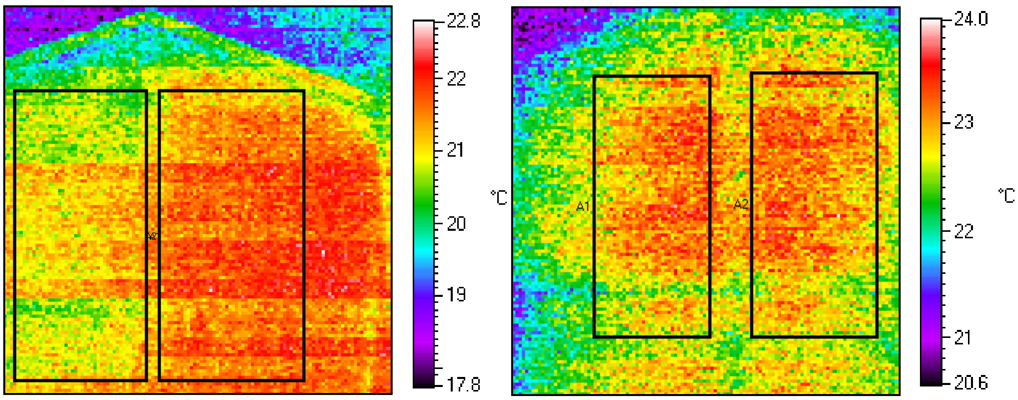

Figure 6: Images obtained by thermovision camera: (a)Ceiling above old window in observed building (b) Ceiling above new window in observed building

In this particular experimental research, retrofitting included exchanging of old wooden windows with new PVC and also reconstruction of dormer which caused high ventilation loss. Reduced heat losses after renovation can be seen in Figure 6. Performed measurements showed increase of mean temperature on glass window of 3°C. Based on the results of measurements on this project, it was concluded that number of mean exchange of air decreased from 15.5 changes per hour to 0.5 changes per hour in reconstructed room.

Although measurements for improving thermal envelope can give good results theoretically, there are also practical problems in retrofitting, which results with different EE performance than projected. Also, by analyzing construction projects and the construction quality of the majority of residential buildings in the Serbia and regional countries, it was concluded [1] that situation is not satisfactory, even in the cases where project predicts proper insulation and other energy-efficiency related measures.

That is why it is important to define and establish mechanisms for supervision and methodology for quality control (e.g., air tightness measurements, thermography, frequency of measurements, sequence of implementation) of performed construction work that effects the thermal envelope of building.

5 CONCLUSIONS

In this paper, importance of partial renovation of thermal envelope is presented through calculation of decreased energy needed for heating and experimental observation on retrofitted objects. Both of these approaches indicated that installation of windows can significantly improve energy efficiency, and that this analysis can be especially important in attic.
State of energy efficiency in Serbia is presented and it is obvious that high energy consumption in buildings should be reduced. In existing buildings, renovation projects could substantially contribute to this cause.
In order to increase number of objects renovated with respect to energy efficiency, non-technological barriers should be removed. Moreover, legal environment should potentiate projects of cost-benefit analysis for buildings in public and private sector by enabling conditions to finance deep renovation of buildings.

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ПОБОЉШАЊЕ ЕНЕРГЕТСКЕ ЕФИКАСНОСТИ ЗГРАДА У ГРАДСКИМ СРЕДИНАМА

Резиме: *Иако постоји велики број објеката са великом потрошњом енергије у Србији, постоји могућност да се та потрошња смањи улажући у обнову тих објеката. Прозори и врата, као део термичког омотача зграде, играју веома важну улогу у укупној енергетској ефикасности зграде. У овом раду су приказани како се може смањењити потрошња енергије у зградама у градском подручју на примерима реновирања објеката, као и одговарајућим експерименталним мерењима. Реновирање објеката подразумева замену прозора и спољашњих врата, док су експериментална мерења обављена снимањем термовизијском камером. Ова мерења указују на значај уградње одговарајуће столарије као важног дела топлотног омотача зграде. Поред тога у раду су приказани и одговарајући подаци о укупном стању енергетске ефикасности зграда у Србији.*

Кључне речи: *Енергетска ефикасност зграда, реновирање, мерења*