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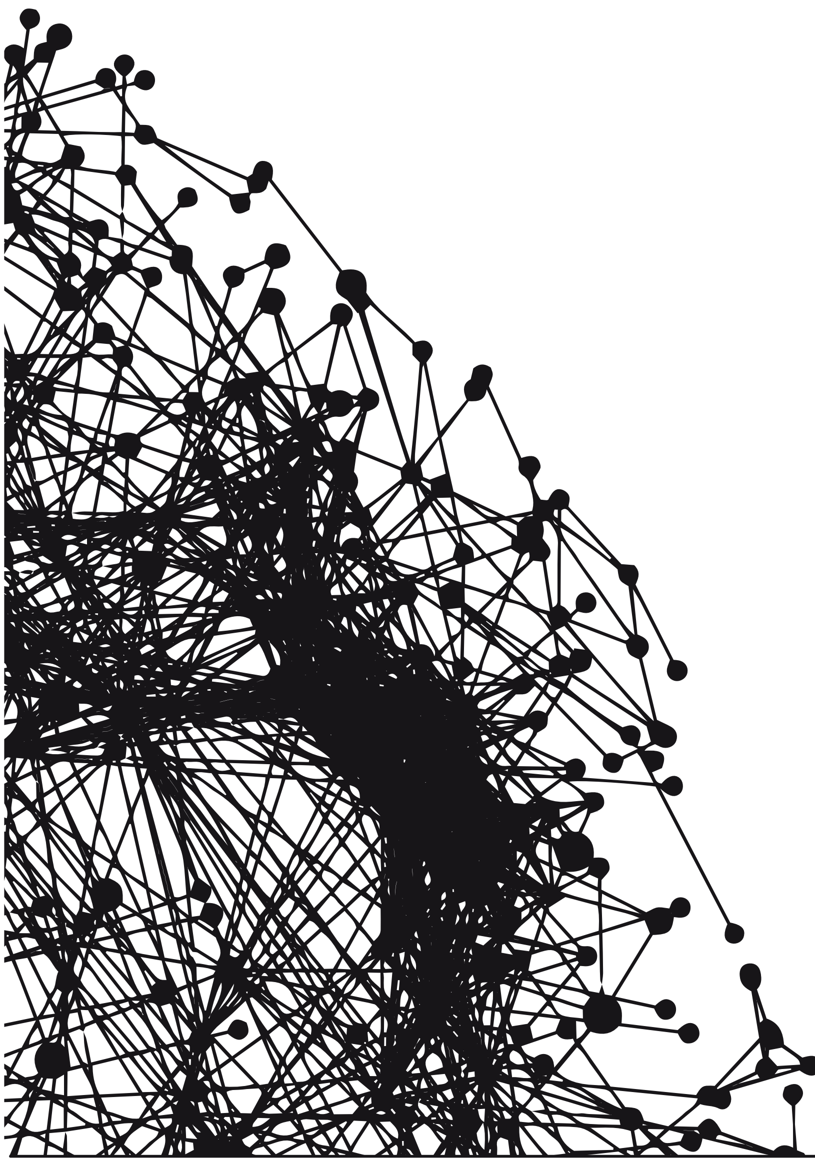

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POSSIBILITIES FOR ENERGY REHABILITATION OF TYPICAL SINGLE FAMILY HOUSE IN BELGRADE - CASE STUDY

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ABSTRACT

Paper presents a case study of refurbishment with energy efficiency upgrade of a family house in Belgrade. Analyzed building is a typical representative of family housing stock, based on the national typology of residential buildings, developed during TABULA project, which resulted in definition of models for energy efficiency upgrade and recommendations for reconstruction of each housing type. In this paper possibilities of application of these principles in a real life situation are presented, and several options for each proposed measure are discussed. Some basic building data from calculations of energy performance of refurbished building and hypothetical model of building with maximum activated thermal envelope are summed up and discussed. Evaluation of achieved results and measurements of real consumption is in progress.

Keywords: single family housing, refurbishment, energy efficiency upgrade

INTRODUCTION

Based on the methodology for structuring and evaluation of Serbian housing stock, developed during TABULA project, national typology of residential buildings (Jovanović Popović et al, 2013) is defined, together with models for refurbishment of residential buildings, both for family and multifamily housing. These models were defined as two levels of improvements, standard and advanced, which include improvements of all elements of thermal envelope, as well as improvements of the heat supply and hot water supply system. However, not all of these measures are always possible to carry out in practice. This paper presents a case study of a refurbishment of a house in Belgrade, a typical representative of family housing stock, identified in the national typology. It was done in accordance with regulations regarding energy efficiency (2011), which set the energy rating target for refurbishment of existing buildings as an upgrade for two levels. Applied measures and achieved results are described and discussed, while detail evaluation of achieved results and measurements of real consumption is still in progress.

Characteristics based on national building typology

Analyzed building represents type E1 of national residential typology, which is a free-standing house, built in the 70s. Representation of this type in the whole residential housing sector and its energy consumption is shown in **Figure 1**. It also represents almost 22% of family housing stock (Jovanović Popović et al, 2012, p.16), which is the second most represented type. Large number of dwellings and living space, as well as continuous interest for living in this type of houses emphasizes the importance and necessity of their refurbishment, both for reasons of energy conservation, but also for improvement of the overall living standard. These are two inseparable issues, as this case study affirms. Also, since this type of houses, as well as majority of single family houses, is not connected to district heating, but is heated individually, and pays heating bills based on consumption, interest for refurbishment among the target group of its owners is rising. Thus, the aim of the energy rehabilitation should not be achievement of certain energy rating, but significant improvement in thermal comfort and lowering heating consumption and expenses (Ignjatović et al, 2012).

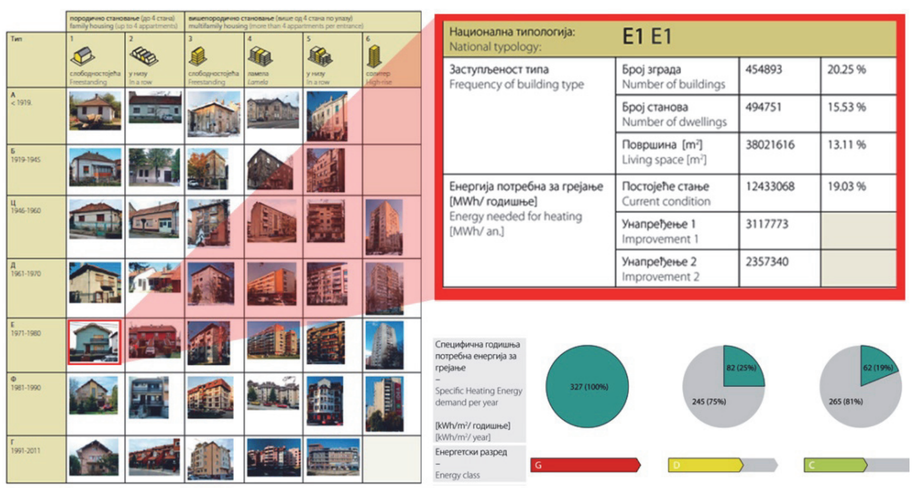


Figure 1: National typology matrix with highlighted E1 analyzed type and its characteristics

This type is characterized by massive external walls, built of solid brick or hollow blocks, compact, rectangular floor plan and unheated basement and/or attic storey. Percentage of façade openings is relatively moderate (less than 50% of the façade area), and windows are wooden, double frame and double sash, with single glazing. Energy consumption ranks this type into G energy rating (over 250 kWh/m^2/year).

Also, one of relevant characteristics for entire family housing stock, which significantly affect energy efficiency, as affirmed in the presented case study, is the heated area compared to the entire living area. In only 30% of houses more than 70% of living area is heated, while in 25% heated area is less than $25m^2$ (Jovanović Popović et al, 2012, p.20). This affects important characteristics of thermal envelope, such as its area to external vs. unheated conditions, as well as building's surface area to volume ratio.

Although the national typology, according to TABULA methodology, defines three sets of measures for improving energy efficiency for each type (construction interventions on the building thermal envelope, improvement in the heat supply system and improvement in the domestic hot water supply system (Jovanović Popović et al, 2013, p.17)), only construction interventions will be discussed, since in the case study presented in this paper only these measures were conducted. Construction interventions measures defined for E1 house type, for first level of improvements are:

- addition of 10cm of thermal insulation on external wall,
- insulation of floor construction to external area with 15cm of thermal insulation,
- insulation of floor construction to unheated attic with 10cm of thermal insulation,
- insulation of floor construction to unheated basement with 10cm of thermal insulation,
- replacement of windows with new ones (double-glazed low-E glass unit, U value cca. 1.5 W/m2K), and
- replacement of doors with new, thermally insulated.

Application of these measures results in achieving D level of energy certification, and lowering consumption of heating energy for 75% (from 245 to 82 $kWh/m^2/year$).

Case study

The analyzed house is located in Belgrade suburb. It was built in the beginning of 70s, as a double house, in massive type of construction. Originally it consisted of two identical single family living units, of cca. 280 m^2 living area (140 m^2 per household), with unheated basement and attic storeys. One unit is subject of this case study. It was altered significantly in previous years, by additional volume in different materialization, and finally recently refurbished. Calculations of energy consumption were carried out for two scenarios of heating regimes: first regime is the real state, where only a part of total living area is heated, and second, hypothetical, where whole living area is heated, and maximum thermal envelope is activated. Appropriate plans of these two scenarios are shown in Figure 2.

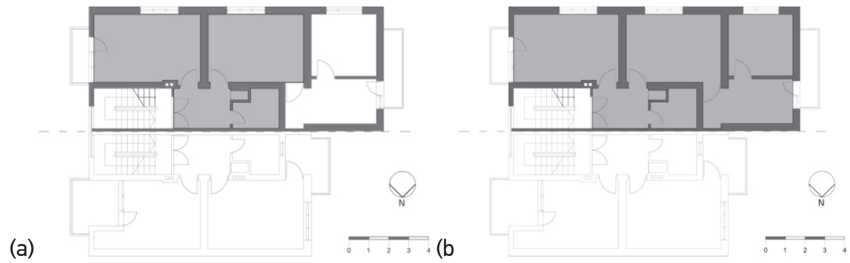


Figure 2: Floor plan corresponding to the real state scenario of heating area (a) and whole living area heated (b)

Existing state

The analyzed unit has dominant south orientation of the main facade (Figure 3a), and due to its corner position it has an unshielded, exposed position. Its external walls are solid brick walls of 38cm and 25cm. Thermal imaging (Figure 3b) shows even distribution of heat losses through the wall area, except in the zones of vertical and horizontal concrete reinforcements, which show significant linear losses. Heating sources can be easily spotted which indicates inadequate performance of the external wall (solid brick wall of 25cm, and sandwich wall with 5cm of insulation in the added volume). Energy carrier for heating is gas, and since it was installed recently, upgrade of the system was not considered. The added volume is not evenly heated, so it can be considered that the real thermal envelope ends with the inner wall to unheated space on the west side.

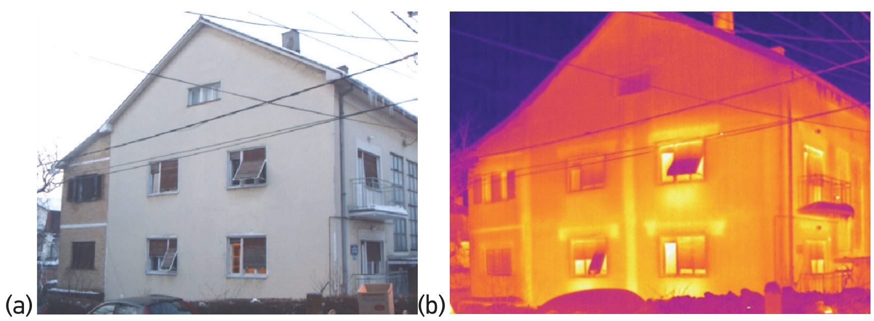


Figure 3: Thermal (a) and visual (b) images of building before refurbishment

Refurbishment options

Since there was a need for creating another living unit in the building, decision about the refurbishment followed the decision of adaptation of attic storey into an apartment. Since the budget was limited, several options for balancing costs and quality were considered. The facade was in bad condition, both functionally and aesthetically, so it was decided that it will be completely refurbished. Choice between EPS slabs and rock mineral wool insulation was made in favour to the latter, because of its fireproofing capacities and permeability. Although more expensive, contact facade with 8cm of rock mineral wool was considered a long lasting and high quality solution (Figure 4a). Windows replacement was a significant budget issue, so it was decided to go for a standard practice solution. Aluminium frames with thermal brakes and double glazing were chosen instead of PVC solutions, because of large window openings, as a long lasting solution, where superior quality glasses could be considered as a replacement option in following years. Roof was rehabilitated without completely changing the roofing and installing new layers of boards and battens, from the inside, by thermally insulating with combination of mineral wool and EPS slabs between rafters (Figure 4b). Floor construction towards basement was not insulated, as well as interior walls toward unheated staircases.

(a) (b)

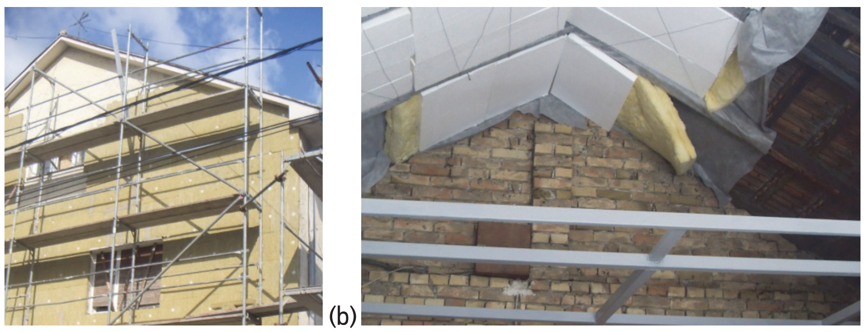


Figure 4: Details of contact facade construction(a) and roof insulation (b)

Refurbished building

In Figure 5a building after refurbishment is shown, and the appropriate thermal image (Figure 5b) shows performance of the refurbished main, south facade. Areas insulated additionally from the inside (room in the upper right corner) can be detected, as area of lower temperature on the facade. Several spots on the central area of the facade, showing higher temperatures, indicate flaws during installing slabs of rock mineral wool, and existence of small gaps between them.

(a) (b)

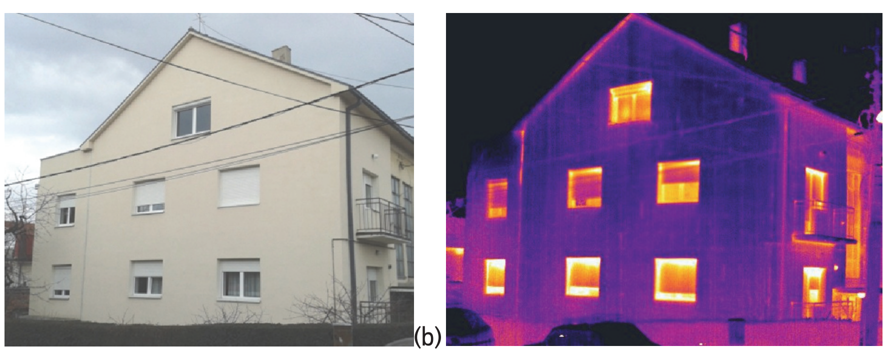
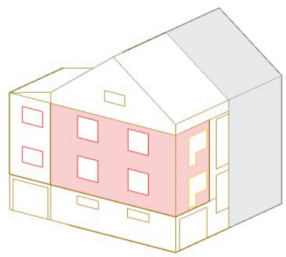
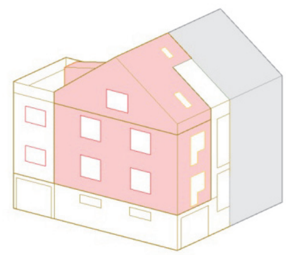


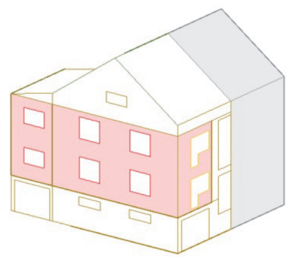
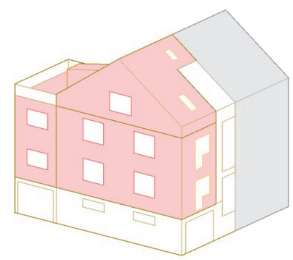
Figure 5: Thermal (a) and visual (b) images of building after refurbishment

Table 11: Compilation of relevant building data for calculation of energy performance prior and post refurbishment – real thermal envelope

	Existing state prior to refurbishment: real thermal envelope	Refurbished case: real thermal envelope
		
Heated area [m^2]	**91.16**	**141.11**
Heated volume [m^3]	**346**	**523**
Area of envelope to external [m^2]	**93.08**	**216.51**
Area of envelope to unheated [m^2]	**232.81**	**218.18**
A/V [m^{-1}]	**0.94**	**0.83**
Qh, an [W/m^{2}K]	**342.33**	**146.07**
CO_2 emission [kg]	**6865.53**	**4534.51**

In Table 1 some relevant building data for calculation of energy performance prior and post refurbishment are given. Pink colour in the images indicates heated volume. This table shows calculations for real thermal envelope, without unheated areas of the building. Software for calculation used is *KnaufTerm2Pro v22*, available online as a freeware. Calculated consumption of the original state building was above 300 W/m^{2}K, which corresponds to the G energy rating, while the consumption of the refurbished building is almost 60% lower, 146.07 W/m^{2}K, which corresponds to E energy rating, which fulfils, and even exceeds current regulations (2011). Better surface area to volume ratio of the refurbished case is the result of including a relatively large volume of space into heating volume. Also, favorable south orientation and unshielded position significantly contribute to the solar gains and passive heating, since calculations shifted to northern orientation give consumption of 175 W/m^{2}K (20% increase), corresponding F energy rating.

Table 2: Compilation of relevant building data for calculation of energy performance prior and post refurbishment – maximum activated thermal envelope

	Existing state prior to refurbishment: maximum activated thermal envelope	**Refurbished case: maximum activated thermal envelope**
		
Heated area [m^2]	**132.16**	**182.11**
Heated volume [m^3]	**534**	**711**
Area of envelope to external [m^2]	**176.53**	**320.62**
Area of envelope to unheated [m^2]	**254.42**	**204.03**
A/V [m^{-1}]	**0.79**	**0.74**
Qh, an [W/m^{2}K]	**279.54**	**132.45**
CO_2 emission [kg]	**8127.67**	**5306.66**

In Table 2 a hypothetical case of maximum activated heated volume (without considering basement level) is presented. Consumption and savings percentage is lower both prior to reconstruction and after refurbishment than in the previous scenario. Surface area to volume ratio in both cases is significantly better than in previous case of smaller heated volume, but its decrease in this scenario is less than in previous, which can be explained by significant increase in area of envelope in contact with external conditions. Also, since additional activated heated area is located in part of the house that was added in the 90s, and its external walls have improved thermal characteristics (sandwich wall with 5cm of thermal insulation), its thermal behavior is also better than in the first case, when the original wall (solid brick wall of 25cm) is exposed to unheated area.

Conclusions

This paper presents a case study of a refurbishment of a single family house, which was done according to current regulations, but without ambition for superior energy performance, due to the budget limitations. Favorable orientation, as well as good proportions of heated volume enabled significant savings of almost 60% in energy consumption with relatively modest refurbishment measures. Since the analyzed building represents a numerous type of single family houses, built almost 40 years ago, which mostly didn’t went through appropriate refurbishment in the past decades, this study presents some possibilities of its rehabilitation, while highlighting correlations between energy efficiency upgrade and possibilities for improvement of spatial and living comfort.

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