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Aleksandra Krstić-Furundzić[1], Tatjana Kosić[2], Marija Grujić[3]

ENERGY, ECOLOGICAL AND ECONOMIC ASPECTS OF IMPROVEMENT OF THE DWELLING HOUSING IN BELGRADE

Summary

The main concern of this research is building refurbishment. Different possibilities of energy performances improvement of existing dwelling housing in the settlement Konjarnik, Belgrade, Serbia, are estimated from energy and economic point of view. Two hypothetical models of improvement of building envelope are created. Different solutions for reduction of energy consumption for heating of existing dwelling housing as well as reduction of CO2 emissions are considered in economic analyses. Economic analyses use BLCC (Building Life Cycle Cost) software which produces multileveled grading of building scenarios and comparative analyses of grading results. The comparative analyses take into account initial building investments and energy cost savings through certain period of building`s use. The overall behaviour of different scenarios is measured according to: (a) initial/capital investments, (b) energy costs (c) operating, maintenance, and repair (OM&R) costs and (d) capital replacement costs. Results of the analyses are used as quantitative inputs for investment decision making.

Key words

Energy savings, dwelling housing, refurbishment, investment project, life cost analyses

ENERGETSKI, EKOLOŠKI I EKONOMSKI ASPEKTI UNAPREĐENJA STAMBENOG OBJEKTA U BEOGRADU

Rezime

Predmet ovog istraživanja je obnova zgrada. Različite mogućnosti unapređenja energetskih performansi postojećeg stambenog objekta u naselju Konjarnik, Beograd, Srbija, su analizirane sa energetskog, ekološkog i ekonomskog aspekta. Dva hipotetička modela unapređenja omotača predmetnog objekta su formirana. Različita rešenja za smanjenje potrošnje energije za grejanje postojećeg objekta kao i smanjenje uticaja emisije štetnih gasova su razmatrana u ekonomskoj analizi. Za ekonomsku analizu

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korišćen je kompjuterski program BLCC (Building Life Cycle Cost) кoji omogućava vrednovanje korisnosti ušteda energije u životnom veku objekta primenom različitih mera optimizacije energetske efikasnosti omotača zgrade i komparativne analize postignutih rezultata. Početne investicije i postignute redukcije troškova energije za grejanje u određenom periodu životnog veka objekta su uzete u obzir u komparativnoj analizi. Specifičnosti različitih scenarija su izražene kroz troškove: (a) početnih/kapitalnih ulaganja, (b) energije za grejanje, (c) upravljanja i održavanja (OM&R costs) i (d) periodičnih remonta koji su neophodni u životnom veku objekta. Rezultati analize se koriste za donošenje investicionih odluka.

Ključne reči

Ušteda energije, stambeni objekat, obnova, investicioni projekat, analiza troškova životnog veka

1. INTRODUCTION[4]

Up to the seventies the buildings were designed without consideration of energy demands and consumption. According to the data collected by Serbia Statistical Office, about 55 percent of the total of 583.908 existing housing units in Belgrade was built in this period [1]. This figure reveals that Belgrade's building stock has a significant number of buildings which energy performances have to be improved. It should not be disregarded because severe energy and economic savings can be obtained.

All over the world there are lot of prefabricated suburban housing settlements which are characterised by low energy performances. Also, a numerous of suburban settlements had been built in Belgrade after II World War. In that time a few prefabricated systems were mostly in use in our country which resulting in housing settlements consisted of a numerous of buildings with the same or similar layouts. One of representatives of such architecture is housing settlement Konjarnik. Different possibilities of energy performances improvement of existing dwelling housing in this settlement are estimated from energy and economic point of view.

The aim of this paper is to draw attention of professional circles to the possible significant energy and therefore economic/financial savings resulting from implementation of simple measures of building refurbishment. In a milieu of recovering economy, privatization in progress, an expansion of foreign investments, as well as a dynamic real estate market, building refurbishment is regarded as a field with significant perspective of energy and economic savings.

Economic and financial analysis intends to present the assessment of cost-effectiveness and feasibility of energy optimization of the building facade. Cost-effectiveness and justification of energy optimization are graded according to primary energy consumption (within scope of EU-ISO standards).

---

[4] *The study has been carried out as a part of scientific research project "Development and demonstration of hybrid passive and active system of solar energy usage for heating, natural ventilation, cooling, daylighting and other needs for electric power", National Program of Energy Efficiency, funded by Ministry of Science and Technological Development of the Republic of Serbia in the period 2007-2009 (head of project Prof. Dr. Aleksandra Krstic-Furundzic).*

2. METHODOLOGY

Methodological approach includes analysis of energy performances of existing building and improved models, financial analyses of building life cycle costs and savings of both the existing building and two hypothetical energy improved models of the building, and comparative analyses of obtained results. This approach could generally be applicable for analyses of building energy refurbishment investments, while in generalization of outcomes some technical solution and possible economic benefit particularities have to be carefully considered.

2.1. ENERGY PERFORMANCES OF EXISTING BUILDING AND IMPROVED MODELS-E.E. SCENARIOS

The subject of the analyses is one of the central lamella of the 8-storey building, situated in semi-closed block, on the south oriented hillside in dwelling housing in Konjarnik (Fig. 1). Each building consists of 5 rows lamellas, which have a typical floor lay-out with four one-side oriented flats. Analyses of energy efficiency of the building envelope structure of the existing building and the hypothetical improved models are taken into the consideration.

Figure 1. Location and building shape

2.1.1. Existing building envelope structure

The existing building was built in the late sixties of the 20th century as reinforced concrete prefabricated structure. Prefabricated panel structure is the rectangular and compact form, with poor energy characteristics. Longitudinal facades consist of rows of parapets and windows which surfaces represent 70% of the facade and loggias that make 30% of the facade. Parapets are three-layer prefabricated panels (internal concrete 10cm, thermal insulation 5cm, external concrete 5cm) with external finishing layer in ceramic tiles (Fig. 2). Along the edge of facade parapet panel, the concrete frame is present which results in the presence of thermal bridges and exceeding allowed U-value of external wall (actual U=1,034W/m2K; the limit value is 0,9W/m2K for Belgrade as second climatic zone). Speaking in terms of thermodynamics, the windows are to be mentioned as the problem for the both size and inappropriate thermal characteristics (U>3,0W/m2K), as well as the presence of the air infiltration. Windows are box type wooden structures, glazed with float glass of 4mm thickness, with internal cloth blinds.

Figure 2. Typical south-west facade

2.1.2. Improved building envelope structure

Measures of improvement of energy performances of dwelling housing in Konjarnik, which are considered as the most suitable from energy efficient aspect, include increasing the thickness of thermal insulation, thermal bridges brake, increase in thickness of thermal insulation of the attic slab, completely replacement of the windows by modern one, with improved thermal and solar features, and glazing of loggias. Two hypothetical models (MS1 and MS2) of improvement of building envelope are selected, as shown in the Table 1 and Figure 2. Predicted exchanges of the air flow for MS1 is 2 - 3 exchanges per hour, while for MS2 is 0,8-1 exchanges per hour. Increase in thickness of thermal insulation of the attic slab to 22cm-10cm of added hard mineral wool (U=0,171W/m2K) is predicted for the both models.

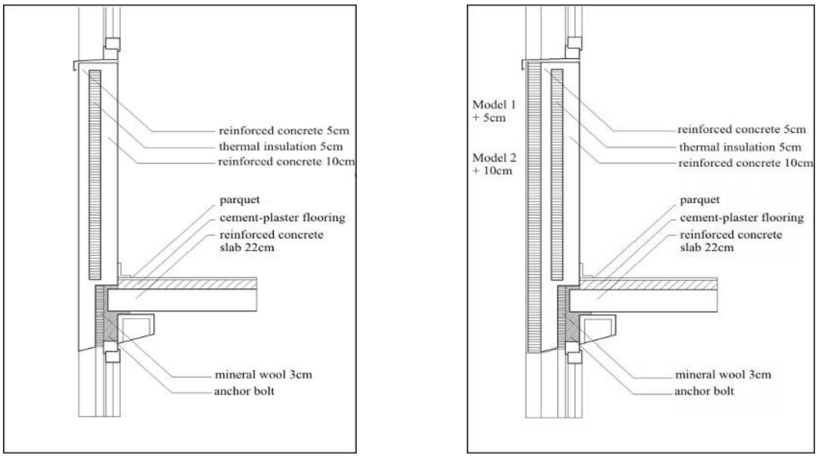

Figure 3. Envelope structure of the existing building and the improved models

2.1.3. Energy efficiency assessment

Assessment of energy savings and increasing energy efficiency in residential building was done on the basis of the results of the thermodynamic simulation of the existing building and the improved models (Table 1), taking into account the climatic conditions for territory of Belgrade [2].

Table 1. Contribution of building envelope structure improvement to the annual energy savings

Type of model (scenario)	**Measures of building envelope improvement**		**Annual energy consumption for heating (kWh)**	**Savings %**
	Thickness of wall thermal insulation	**Type of glazing**		
Existing MODEL	5 cm, k=0,67W/m^{2}K	Box type window with float glass (4mm), U>3,0W/m^{2}K	353810,00	
MODEL MS1	10 cm, k=0,371W/m^{2}K (5cm of added expanded polystyrene)	Glazing of windows and loggias: double glazed (4+12+4); five-chamber pvc profile; U=2,3W/m^{2}K	37242,89	66,5
MODEL MS2	15 cm, k=0, 255W/m^{2}K (10cm of added expanded polystyrene)	Glazing of windows: triple glazed (4+12+4); five-chamber pvc profile; U=0,9W/m^{2}K	18446,15	83,4
		Glazing of loggias: double glazed (4+12+4); five-chamber pvc profile; U=2,3W/m^{2}K		

It is evident that increase in thickness of thermal insulation, replacement of the type of the glazing in relation to existing building and glazing of loggias achieve energy savings for heating from of 66,5 to 83,4%.

2.2. ECONOMIC ANALYSES OF BUILDING LIFE CYCLE COSTS AND SAVINGS

The applied methodological procedure is a comparative economic analysis of the model of the existing building and two models of the building energy improvement. A comparative analysis takes into account initial building investments and energy cost savings through certain period of building's use. Each improved model of the building facade and energy consumption for heating is compared to the model of the existing building and its energy consumption, and each new scenario has a different initial investments. The overall results of different scenarios are measured according to: (a) initial/capital investments, (b) energy costs (c) operating, maintenance, and repair (OM&R) costs and (d) capital replacement costs.

This economic/financial analysis was carried out using BLCC (Building Life Cycle Cost) software [3]. Software was developed in USA and it is used for calculation of buildings life-cycle energy savings. With certain modifications, this software was used for the analyses of several investment projects in Serbia which required feasibility study for different models of optimization of the facade, building structure, lighting and heating system [4].

Criteria for the evaluation of the analyses results are divided in two groups [5]:

- The criteria for the evaluation of efficiency of the each scenario include:
  - Adjusted Internal Rate of Return (AIRR),
  - Net Present Value (NPV) and
  - Simple Payback Period (in years).

- The criteria for evaluation of external effects include:
  - protection and conservation of the environment,
  - sustainability of energy resources,
  - rationalization of investment funds and
  - impact on technical progress.

Final assessment of the design efficiency of the project and its scenarios (using computer software BLCC) is expressed in three areas:

- assessment of financial and market efficiency of the design, which determinates feasibility of the investment under the real market conditions, measured by accumulation,
- assessment of social and economic efficiency of the design which evaluate the effects on social and economical development of the country,
- assessment of efficiency of design under changing conditions of the key parameters, or assessment of sensitivity of the project under aggravation of estimated conditions.

In final analysis design scenarios are ranked by each criteria involved. BLCC software provides choices such as:

1. design scenario which is most favourable in terms of lowest life cycle cost,
2. design scenario with shortest Simple Payback Period,
3. design scenario with lowest emission of green house gases.

When the first two criteria viewed as an equivalent choice would be the solution that best meets both conditions.

2.2.4. Efficiency criteria

Usually economic life cycle is determined within period of 10 years. However, in housing design especially, economic life cycle can be significaly prolonged - more than 10 years, due to the inevitable obsolescence of applied technology. In this case, the rational period of exploitation of the building is 25 years.

Adjusted Internal Rate of Return (AIRR) represents the discount rate which present investment value reduces to zero. AIRR in this case was calculated for the economic life cycle period of 25 years. This data indicates optimal ratio of income (savings) and expenses (costs) during economic life cycle of a building.

Net Present Value (NPV) is the sum of income during building life cycle which is reduced to its value of the first year of its life cycle (present value). NPV presents an absolute indicator of profitability of the design because it takes into account the time preferences and, using discounting technique, it reduces effects of any future design to their present value. For practical reasons, the initial investment period of building economic life cycle (beginning of investment studies) is taken as base time for calculation of NPV. Discounting is performed according to previously established discount rate (usually the individual discount rate that makes the weighted arithmetic mean of real interest rates on funding sources). The discount rates of 10-12% are traditionally used by The World Bank for all funded projects. However, as the entire calculation in this study was done in euro currency, the average interest rate in Western Europe was taken into account. In this case, NPV is calculated for savings - as a kind of design profit.

Simple Payback Period (SPP) - refers to necessary time (in years) for return of initial investment. Invested funds are returned in the year when the cumulative net effects of economic life cycle become positive. The aim is to reduce a payback period (value SPP), to be as short as possible, and the acceptable payback time of the initial investment is before the end of last year of economic life cycle. Data such as initial investment, annual costs and savings during life cycle of the design are used to calculate SPP. Building Life Cycle Cost (BLCC) software operates with simple payback period, which is simple ratio of initial investment increased for all annual costs and savings (as the equivalent of income in one year).

2.2.5. External effects

External effects are represented by different social and economic effects which don’t have to be quantified. For improvement of energy efficiency these effects are of great social benefits, like preservation of environment and non-renewable resources, like influence on technical progress, quality of life of the population and so on.

3. RESULTS

Economic assessment of the improvement of the building energy performances is presented through investments, energy consumption costs and building life cycle cost.

3.1. INVESTMENT

Initial investment is considered as onetime expenses in the first year of economic life cycle of design. Each improved model has a specific increase or reduction of investment in comparison with basic design. Table 2 and Table 3 show total and additional investment of specific scenario.

3.2. ENERGY COSTS

In every scenario there are various solutions for reduction of energy consumption which results in different annual energy costs reduction. The adopted price for electricity was 12 cent/KWh and as such was used as input for all calculations. Thermal energy from the city's network was calculated at the level of 10 cents/KWh. Basic assumption is that inflation has a neutral effect on building life cycle if price relations (parity of prices) do not change in life cycle or if impact of inflation is identical on both income and costs of the building.

3.3. LIFE CYCLE COST ANALYSIS

Life cycle cost analysis is performed for each proposed model-scenario of the building design. Each scenario gives different measures for improvement of buildings energy efficiency. Using BLCC (Building Life Cycle Cost) software Net Present Value (NPV) is determined for each scenario, and the best solution that gives the best results during the life cycle (the period of 25 years) was chosen. All future costs are discounted to present value using a real discount rate of 3.3%. Results of LCC analysis are given in Table 2 and Table 3.

Table 2. Results of LCC analyses for scenario/model MS1 and MS2 in comparison to basic model (existing condition of the building)

Model/scenario	**initial investment costs (€)**	**total annual heating energy costs (€)**	**operating, maintenance, and repair (OM&R) costs (€)**	**LCC**	
EXISTING MODEL	-	35.381,00	1.000,00	620.058,00	
MODEL MS1 – light investment	117.180,00	3.724,29	1.000,00	203.923,00	*
MODEL MS2 – significant investment	141.910,00	1.844,62	2.000,00	220.986,00	

Table 3. Life cycle savings for models MS1 and MS2

scenario	**total increase of investment costs (€)**	**total annual reduction of costs - heating energy (€)**	**Simple Payback Period (SPP) (year)**	**Adjusted Internal Rate of Return (AIRR) (%)**	**Operational Savings per one year (€)**	**Total Discounted Operational Savings (€)**	**Savings to Investment Ratio (SIR)**	
MODEL MS1 – light investment	117.180,00	31.656,71	3,70	9,62	31.657,00	517.121,00	4,41	*
MODEL MS2 – significant investment	141.910,00	33.536,39	4,23	9,04	33.536,00	547.826,00	3,86	

Analyses of impact of green house gases emissions on the environment shows that undoubtedly the most economical scenario is MS2, which has the lowest energy consumption and thus the lowest emissions.

Table 4. Green house gases emissions

	EXISTING MODEL		**MODEL MS1 – light investment**		**MODEL MS2 – significant investment**	
	Annual emissions (kg)	**Life-Cycle emissions (kg)**	**Annual emissions (kg)**	**Life-Cycle emissions (kg)**	**Annual emissions (kg)**	**Life-Cycle emissions (kg)**
CO2	313.189,77	7.828.672,49	32.967,11	824.064,86	16.328,38	408.153,72
SO2	746,80	18.667,57	78,61	1.964,99	38,94	973,25
NOx	657,33	16.430,94	69,19	1.729,56	34,27	856,64

4. CONCLUSIONS

The following conclusions can be listed:

- LCC of the improved models are significantly lower in comparison with the existing model but the results of the both improved models are almost the same.

- According to the LCC analysis for different scenarios/models the most cost-effective is model MS1, although the reduction of energy consumption for scenario MS2 is more than twice lower (compared to scenario MS1). The reason for such LCC analysis results is the maintenance costs for scenario MS2, which are doubled in comparison to maintenance costs of scenario MS1.

- Building life cycle savings analyses shows that scenario MS1 has shorter Simple Payback Period -SPP (3.7 years) than scenario MS2 (4.23 years). This scenario also has lower increase of investments and higher Savings to Investment Ratio (SIR).

- Thus, from the standpoint of economic/financial analysis, more profitable scenario is MS1 or scenario with moderate investments. Even if we don't take into consideration the maintenance costs (or if we slightly decrease them), scenario MS1 would be more profitable because the other criteria are more important - criteria of lower investment and quicker return of investment.

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