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Economically feasible energy refurbishment of prefabricated building in Belgrade, Serbia

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The main objective of the presented paper was to evaluate the integrated design strategies applied in refurbishment of the prefabricated residential housing, erected in ′70 in the New Belgrade, Serbia, in order to achieve energy savings accompanied with reduction of CO_2 emissions and improvement of households' health and comfort. Conducted study led to the preliminary design of energy refurbishment of the existing building, and its conversion to energy efficient building with minimized loads. Building's dynamic behavior and energy efficiency have been optimized implementing BPS-Building Performance Simulation. Very significant reduction of thermal and cooling loads with the reference to the building's existing status is obtained. Refurbishment encompassed comprehensive optimization of building's envelope structure, natural and mixed ventilation. The implementation of a series of EEI (energy efficiency improvement) measures resulted in significant reduction of buildings energy loads. The investment in energy efficiency retrofitting can improve macroeconomic stability and contribute to the sustainable economic growth. Furthermore, economic analyses were performed for each model, considering present economic situation in Serbia and availability of funds for refurbishment. Presented methodology and results of the performed analyses offer an opportunity to extend their application to other neighborhoods, exploring refurbishment potential results if applied on a greater urban scale.

1. Introduction: energy refurbishment of residential buildings

Increasingly, we are witnessing "weather extremes" with catastrophic consequences. Numerous experts in the field of climatology believe that these events are meteorological – geological manifestation of global warming. Depletion of fossil energy resources, climate change and environment pollution threaten the life support systems on Earth. To stop further progression of these irreversible processes, necessary is further to be developed RES (renewable energy sources) technologies, proceeded with the spreading of their utilization. However their efficient and cost-effective implementation must be preceded by the improvement and optimization of energy efficiency. All kind of energy loads are to be reduced to the lowest possible level, by the application of all known available measures, knowledge, technology and energy-efficient systems and equipment. Energy efficiency in buildings is particularly important due to the buildings highest share in the overall energy use, and the fact that extremely large potential savings can be obtained particularly in buildings [1].

After the first energy crisis in 1973 and raised concerns about exhaustion of fossil fuels, most building standards concentrated on energy efficiency, and not any more only on health, safety and occupant comfort. First political acts were brought to America in 1975, (*ASHRAE published Standard* 90–75), and then in Germany in 1977, when the first German regulations on energy saving energy in buildings were introduced [2]. The European Union has played an important role in the development of two major acts, in 1992. The United Nations Convention on Climate Change (UNFCCC) and the Kyoto Protocol, adopted in 1997, under which countries ratify to take target values of quantified emission reduction (GHG) in a certain time. The Kyoto Protocol entered into force in Serbia on 16th February 2005. Until now more than 170 countries have joined it.

In 2002 the EU adopted its first directive on the energy performance of buildings (EPBD), which points out the minimum requirements for new buildings and renovation of existing ones. In 2010, EU did adopt the transposition of the first directive in the form of document (EPBD 2010/31/EU). This innovated EPBD

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Nomenclature

C_N	heating energy bill, nominal charge
C_C	heating energy bill, prior to the retrofit, allocated cost model
C_R	heating energy bill, after the retrofit
P_{hf}	price of heating–fixed component, annually, (€/m^2)
P_{hv}	price of heating–variable component, (€/kW h)
P_{hn}	price of heating–nominal charge, annually, (€/m^2)
ROI	return on investment.

document requires from every Member States to establish new plans to improve the energy efficiency of buildings by introducing a new methodology called "cost optimality" analysis. The most current EU plan set new measures and new targets to be achieved - by 2020, when every new building in the EU must be "nearly-zero" energy, and by 2018, every public building, whether newly constructed or renovated, must be "nearly-zero" energy with minimized loads covered exclusively by renewable energy sources.

The refurbishment of the existing buildings has a fundamental role to win these challenges, and without any doubt their great numerical superiority in relation to the new buildings, represents a major sector for achieving overall goals for energy savings and reduction of Serbia's CO_2 emissions level, as well as globally.

Newly built buildings designed by bioclimatic and self-sustainable principles in architecture are to contribute significantly to the reduction of CO_2 emissions, in particular Zero energy buildings, and even more Energy Plus buildings which have a positive energy balance (the building produces more than it consumes). However, only the reduction of CO_2 emissions that comes from the deep energy refurbishment of the existing buildings, can compensate, in a certain way, an additional increase of CO_2 emissions due to the construction of new buildings - related to the embodied energy of production of materials, components, as well as use of construction machinery, during the construction process of new buildings.

2. New Belgrade's residential blocks

The municipality of New Belgrade, one of the 17 districts in Belgrade, occupies 4.096 ha and consists of 72 blocks. The basic physical characteristics of the area's flat terrain are total of 3.47 km^2 green spaces, which represent 8.5% of its surface. Most of these buildings are residential, apartment buildings built after the World War II, between 1950 and 1980. That was a period of the intensive socialistic construction style of work, and general architectural—modernist approach of that period gave rise to a large number of prefabricated residential buildings, nowadays characterized by the excessive final energy demand. The aerial view (Fig. 1 – left) shows the urban planning of these residential blocks and one of the typical façade (Fig. 1 – right) nowadays. Most of these buildings didn't have any sort of reconstruction or refurbishment from the beginning of its life cycle.

Architecture and urban planning principles used to design and build New Belgrade, with modest reduced-size of apartments, with spacious green areas between blocks of buildings and natural ventilation, coincide in many points with the current sustainable urban development approach that promotes quality of interior and exterior living space with minimal impacts on the environment.

Unfortunately, the last 20 years, many new buildings were built outside the context of the architectural and urban heritage of New Belgrade, and with improper behavior of the tenants to the building and its surroundings. Poor maintenance over the years resulted in changed panorama of New Belgrade, as the aesthetically unmatched mix of new "hi-tech" commercial-office buildings and dilapidated residential housing with visibly damaged facades, side by side.

Majority of these buildings have oversized secondary heating systems and boilers or substations if connected to the Belgrade DHS - district heating system. An, recent in depth analysis of measurement and monitoring results of delivered heating energy to the whole building stock within the Belgrade DHS did show that the average values of the annual specific heating consumption (period 2006–2008) was 123 kWh/m^2 (measured max 253 kW h/m^2, and min 66 kW h/m^2 [3].

During the time, lack of interest of the tenants for building maintenance and improvement, their social and economic status has led to obvious physical deterioration of residential buildings. To restore the previously existing identity of New Belgrade, which these objects make, it is necessary to find an adequate solution for the revitalization and architectural refurbishment, not only in terms of important energy demand and CO_2 emission reduction, but overall improvement of the life conditions and socio–cultural aspects.

There is indispensable necessity to change, unfortunately growing culture and mentality of the typical consumer lifestyle characterized by selfish indifference for other human beings and environment. Adequate initiatives, the availability of information and dissemination of knowledge is a requirement for changing behavior and the formation of environmental awareness and ethical tenants, which should bring the necessary changes, including harmonization of social relationships of the tenants, especially the younger generation, as well as their attitude towards the environment.

3. Aim of the study

The aim of the study is architectural re-design using "passive" and "active" measures to improve and optimize the energy efficiency of residential buildings and bring them to the quality level which could lead to further advanced development of energy-efficient building construction until reaching zero energy status, set as a goal to be achieved around 2020 in the EU: the minimum possible energy needs, simultaneously improving comfort and overall internal environment quality, using affordable and accessible technologies, respecting bio-climatic design principles and historical legacy of modernist architecture.

The building located in the "Block 70" in New Belgrade, in the street Jurija Gagarina 73 (hereafter JG73) was selected to serve as "case study building". 14-storey building with useful area of 6725 m^2, and conditioned area of 5934 m^2, with an entrance on the east side and one substation of district heating system "Beogradske elektrane," was selected as one of five typologically different buildings in the neighborhood of block 70.

Energy refurbishment project aim, of the selected building, was to advance the understanding of the energy revitalization process at a larger scale and related scope, the impact on the context of the entire housing "Block 70", and in the end to expand this boundaries on the other blocks of New Belgrade, and thereby acquiring and spreading awareness about the possibilities of reducing CO_2 emissions along with simultaneous improvement of general living conditions in the buildings typologically similar to this example.

Conducted case study encompassed an in-depth analysis of building's structure, definition of several scenarios and models of building's architectural renovation, investigating possibilities to implement several potential validated energy refurbishment models with various measures to significantly improve and optimize building's energy efficiency, and approaches their zero energy status.