ENHANCING ENERGY EFFICIENCY BY APPLICATION OF GREEN ROOF IN RESIDENTIAL BUILDING

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Summary: *Improving the energy efficiency in buildings in the Republic of Serbia has been recognized as an area with the greatest potential for reducing overall energy consumption. It also has an indirect impact on improving the quality of life and comfort in buildings, protecting the environment and reducing the emission of harmful gases, as well as reducing the cost of heating. Permanent population increase resulted in the urbanization process that had different consequences for the quality of life and sustainable future. Green roofs in urban areas of developed countries have become a legal obligation and policies and programs that support the greening of roofs are aimed at to preserve the environment and ensure the sustainable development of cities. This paper deals with an analysis of the influence of green roofs on the energy performance of existing buildings in the center of Belgrade. One of the conclusions of this research points out that it is necessary to perform research studies and experimental analyses for the application of green roofs in our climatic conditions. Thus, the research focus should be on legal regulation that would establish calculation and design standards for green roof systems.*

Keywords: *green roofs, energy efficiency, urban environments, legal regulation, sustainability*

1. Introduction

Improving energy efficiency in the building sector represents a significant potential for overall improvement of energy efficiency in the Republic of Serbia. As a member of Energy Community, Serbia is obligated to continuously work on coordination and

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harmonization of regulation with EU policy, in order to achieve optimal energy consumption and environmental protection.

Furthermore, in developed countries, green roofs are recognized as one of the distinguished tools in the struggle against climate changes. In order to ensure sustainable development and improve the quality of human life in urban areas, green roofs are viewed as a new urban space that affects on reducing greenhouse effect, air quality improvement, biodiversity preservation, and atmospheric precipitations management. In [1] it is emphasized that this way, the plots, from which „nature“ has been evicted to make room for buildings, can provide their former aspect. Therefore, the general context of this paper will be focused researching examples of good practice in order to establish strategic, legislative and planning frameworks, as well as policies, programs, and projects that determine and promote the representation of green roofs.

Green roofs can be applied to existing and new buildings, both residential and business categories, but also on the shopping malls, garages, and public buildings. This is important since the urban areas have limited space for green infrastructure. One of the key parameters in the determination of the green roof type is the load capacity of the structure of the existing buildings. The aim of this paper is to provide an analysis of the possible extent of energy efficiency improvement by application of green roof on the existing residential building in Belgrade. Economic analysis and profitability of the proposed project are also given as the additional indicator of the relevance of this type of practice.

2. A review of the situation in the field of energy efficiency in Serbia and in the City of Belgrade

In the Republic of Serbia, the improvement of energy efficiency in buildings has been recognized as the area with the greatest potential for reducing overall energy consumption. It also indirectly could influence on improving the quality of life and comfort in buildings, protecting the environment and reducing CO2 emissions, as well as reducing the cost of heating. In Figure 1, the projection of final energy consumption in Serbia, by sectors, is given.

According to the available data of Strategy for energy development of Serbia, final energy consumption in Serbia in 2015 was 9.255·10^6 tons of oil equivalent (Mtoe) and residential households had the largest share in this amount. Corresponding predictions for the following period are that the increase of the final energy consumption will reach 11.068 (Mtoe) in 2030. However, for the case with energy efficiency measures employment, this value could drop to 9.709 (Mtoe) (possible 11% decrease).

So, energy efficiency domain should be among the highest priority for both government and society in the Republic of Serbia. It is well known that with the Energy Efficiency Law and the Energy Efficiency Action Plan, Serbia has already created a legal framework for the implementation of the most important chapters from European legislation related to the energy consumption of buildings. But, in [3] it is emphasized that despite formal recognition of the significance of energy efficiency improvements in Serbia, the energy situation has not improved so far due to a lot of reasons.

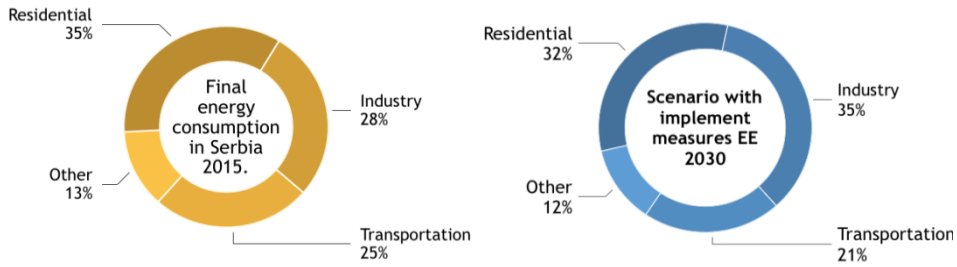

Figure 1. Projection of final energy consumption in Serbia, by sectors, Source:[2]

It is important to note that the administration of the City of Belgrade actively deals with this problem. The current state of energy efficiency in Belgrade is analyzed and presented in City of Belgrade Development Strategy which has a clear conclusion that the future and the progress should be based on sustainable development. Action plan for implementing the Strategy predicts introduction of green roof concept through pilot projects and project: "Green roof of public buildings in the city of Belgrade". Expected results are related to increasing of green areas and forming of concept designs and main design projects.

There are several benchmark practices in cities which implemented some types of projects with green roof systems. Hamburg was the first city which developed a comprehensive Green roof strategy with four "pillars" - financial stimulus, dialogue, regulation, and science. Basel has programs for energy savings and biodiversity protection and Faenza (Italy) has stimulative benefits in the form of increased building areas for investors. All new buildings with flat roof systems or roof with less inclination than 30 degrees should be green roofs, according to the vision to accomplish CO2 neutrality in Copenhagen. Although some of the presented practices could be implemented in Belgrade, before forming the strategy, there is also a prerequisite for creating the building typology in order to perceive the potential of the urban center of the city.

3. Green roofs and energy efficiency

A green roof or a vegetative roof system is a general term that is used informally for all types of roof vegetation. It is as an open space that is covered with plant material and substrate that exists on the roof of a building. They represent the final surface on which the growth of vegetation in the substrate is possible, with many benefits such as collecting water and improving and reducing energy consumption. Their construction consists of several layers: a waterproofing membrane, a drainage layer, filtration felt layer, an organic plant growth environment (substrate or soil) and a final layer of vegetation [4].

The construction of green roofs on flat roofs of existing buildings for the purpose of energy rehabilitation requires that the load capacity of the roof structure of the building should be initially considered. This is a key parameter when choosing the type of green roof. As the total load, the weight of the green roof with saturated water must be taken

into account. Green roofs can be classified according to a type of usage, construction factors, and maintenance requirements, into three different types; extensive, semi-intensive and intensive green roofs. Usually, on existing flat roofs, extensive or semi-intensive green roofs are used due to the limited load capacity of the structure. For new facilities, the financial aspect (initial and maintenance costs) is a decisive factor in choosing the type of green roof.
The green roof typically represents a part of the thermal envelope and therefore it has a direct impact on the energy efficiency of the facilities. In this paper, the improvement of energy efficiency using the green roof is considered, associated only to the energy consumption for heating. This is because domestic legislation does not take into account the consumption of energy for cooling, as well as ventilation of facilities, the use of renewable energy sources, and the application of green roofs themselves.

3.1. Green roofs

The concept and ideas of the green roof are not new because they are common practice in many countries for hundreds, even thousands of years. This concept has undergone various stages over time, and in the twentieth century, it began to be widely applied. More about the historical application of green roofs can be found in [5].
As it is already mentioned, there are three different types of green roofs. Their main characteristics are presented in Table 1 [6].

Table 1. Major types of green roofs and their characteristics [6]

Characteristics / Type of roof	Extensive	Semi-intensive	Intensive
Depth of material	150mm or less	Above and below 1500mm	More than 150mm
Accessibility	Often inaccessible	May be partially accessible	Usually accessible
Fully saturated weight	Low (70-170 kg/m^2)	Varies (170-290 kg/m^2)	High (290-970 kg/m^2)
Plant Diversity	Low	Greater	Greatest
Plant Communities	Moss-sedum-herbs and grasses	Grass-herbs and shrubs	Lawn, shrubs and trees
Use	Ecological protection layer	Designed green roof	Park like garden
Cost	Low	Varies	Highest
Maintenance	Minimal	Varies	Highest

Extensive green roofs are not or barely walkable, they are lightweight and easily feasible and their purpose is technical, remedial or aesthetic. The costs of their construction and maintaining are lower than for other types of green roofs. Intensive green roofs are available for visitors and they are often arranged as gardens or parks, with all the amenities that are featured in classic green areas. They have a considerable weight and need for the irrigation system, so their initial and maintenance costs are considerably higher. Also, they extend the life of waterproofing, and in particular improve the energy efficiency of the building. Figure 2 presents an example of an extensive and green roof with indicated characteristic layers [5].

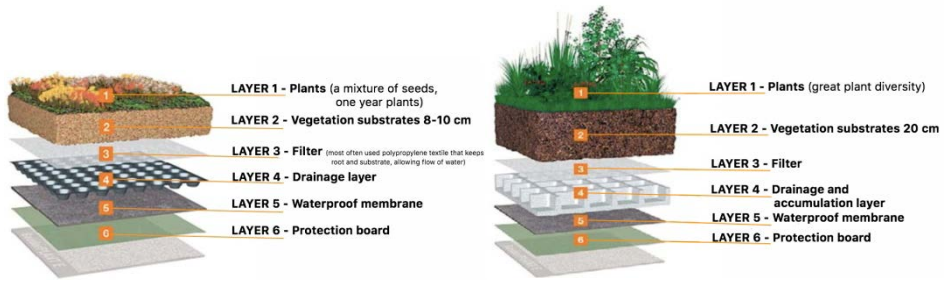

Figure2. Layers in extensive and intensive construction, Source:[5]

3.2. Improving energy efficiency using the green roof

A number of studies conducted for different climatic conditions have confirmed that green roofs greatly reduce energy consumption. For example, in the study [7] it is shown that the ground soil humidity levels have a significant impact on the thermal conductivity of the green roof. Through the combined field measurements and simulations, the effects of different green roof constructions on space peak cooling and heating, annual cooling, and heating loads were analyzed. Based on different green roof structures and planting properties, the analysis showed that simple green roofs can reduce space peak cooling and heating load around 10%, compared to classic roofs.
Given that the domestic regulations do not include the consumption of cooling energy, the analysis provided in this paper only takes into account the consumption of heating energy.
The object of the investigation is the residential building with five floors and a total area of 771m^2, in Kralja Milana Street in Belgrade. It was constructed in 1931 in modern style. This type of building was elected as an example of objects built between world wars since the number of these building in central city core is significant. They are commonly protected by the Institute for the Protection of Cultural Monuments due to their urban architectural value. It should be noted that EU directive from July 2018. brings to a focus energy renovation of existing buildings in order to achieve high efficiency in the building sector. Therefore, this type of building is an appropriate object for potential rehabilitation. However, the measures for improving energy efficiency must be in accordance with the recommendation of a competent institution.

Based on the current energy efficiency regulation, the analyzed building has G energy grade with no elements of the thermal envelope meeting the requirements for the heat

transfer coefficients. Proposed measures for improvement of thermal envelope and overall energy efficiency properties include the installment of semi-intensive green roof and thermal insulating mortar on all facades.

As a consequence of unavailable data about the composition of green roof substrate in our climate conditions and vegetation features that have an influence on thermal properties, the simplified calculation for proposed measures is defined. It was assumed that substrate is in dry condition (0% humidity) and that 10 cm thick layer of insulation was set below the green roof setting. In order to emphasize the effect of the green roof, the flat roof with an identical thermal insulation layer was also considered. It was concluded that surface heat transfer coefficient of projected green roof structure does not exceed limit required by the standard ($U=0.19W/m^2K < Umax=0.20W/m^2K$) while corresponding flat roof needs additional insulation to meet this requirement.

By applying the proposed measures, the annual energy need for heating of concerned building could be reduced from 193.74 kWh/m^2a to 169.64 kWh/m^2a. Also calculated CO_2 emissions could be reduced by about 10% (from 183 kg/m^2a to 166 kg/m^2a). A detailed procedure of this calculation is given in [8].

It should be noted that the participation of an analyzed roof is small in relation to the total surface of the thermal envelope, so it is justified that this analysis could be performed only for the last floor (one apartment) below the roof. In that case, obtained results show that the benefits of the green roof installment are even higher (heat losses for the apartment are reduced by about 25%).

Presented results and effects point out the need for scientific studies and experimental analysis of climate condition influence on hygrothermal properties of soil substrate. Furthermore, legislation needs to standardize the calculation of complex green roof system in order to impartially measure obtained results.

Results of proposed measures are quantified entirely on the decrease of energy needed for heating. Nonetheless, the impact of the presented practice has multiple valuable implications. The new urban area (for gardening, recreation, food production etc.) is generated, which directly increases the value of the apartments. Assessing the energy needed for cooling is not yet defined in the current regulation for energy efficiency in Serbia. Still, it can be assumed that this energy consumption could be notably decreased as well by these types of projects.

Figure 3 shows a comparative display of the heat losses of individual parts of the thermal envelope of the in relation to the entire building and to the apartment under a flat roof, before and after the application the proposed energy measures (installation of the green roof).

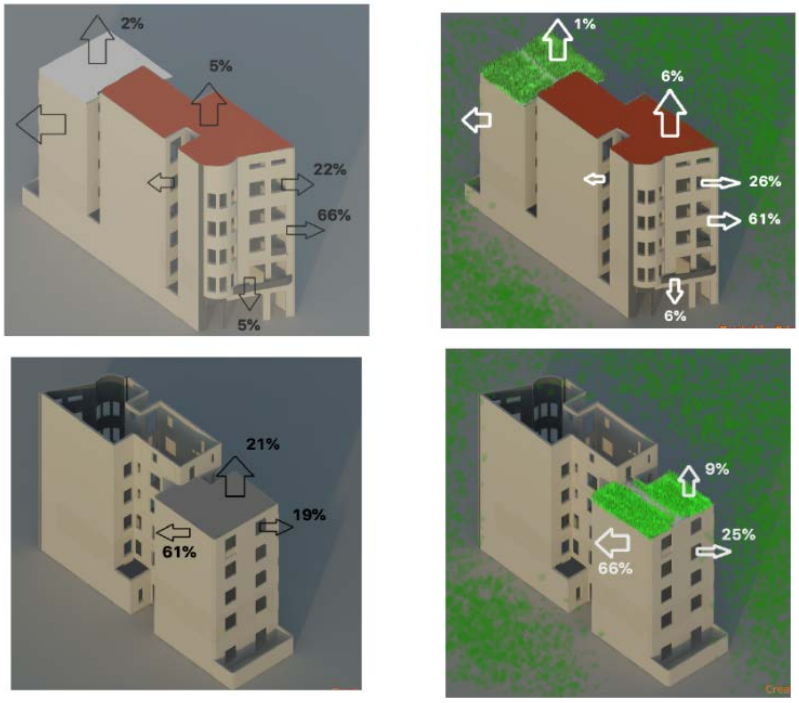

Figure 3. Heat-loss for the building and apartment before and after the applied EE measures

3.3. Economic profitability

Although there are initial high investments for green roof projects, benefits can be seen at the individual and public levels. Reducing the energy needed for heating and cooling, the durability of membranes (hydro-insulation), improvement of acoustic insulation and aesthetic upgrading are the main advantages on an individual level. According to the relevant investigations, public interest in these projects is three times higher than the individual. They are seen through improved stormwater management, air quality enhancement, lessening the thermal island effects, increasing biodiversity etc [9]. By concluding the benefits, it can be said that green roofs are a more appropriate tool for urban environment reshaping, in comparing to other available green or grey areas.

In accordance with domestic regulations, only part of the individual benefits is taken into account in economic profitability analysis. By evaluating the benefits, investment and profit periods for the whole building and the apartment under green roof individually, two life cycle profit analysis are defined and presented in Figure 4.

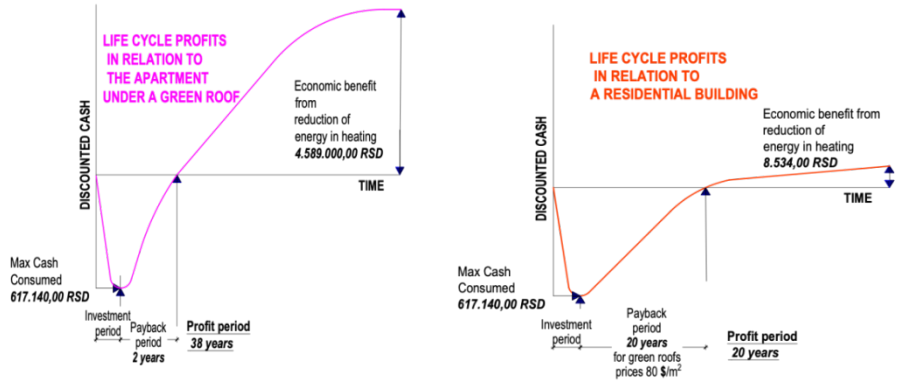

Figure 4. Diagram Life Cycle Profits in relation to a residential building and the apartment under a green roof

4. Conclusions

In urban areas of developed countries, green roofs are recognized as an important tool for environmental protection and improvement of energy efficiency of facilities. Green roofs are not a novelty, but their development, at the beginning of this century, has been spurred by the complex challenges facing cities in the field of energy and the environment.

In this paper, the influence of green roofs on the energy performance of the existing building from the modern period in the center of Belgrade is analyzed. It is shown how much its application reduces the annual energy need for heating and CO2 emissions.

Although the Republic of Serbia has established legislation for energy efficiency improvement, there is a need for completing the regulations in the fields of use of renewable energy sources, calculation of the energy needed for cooling, green roof application etc. It is important to note that the strategy of the development of Belgrade defined the use and the development of the green roofs. In this paper, besides the calculation of the energy performance, the economic analysis of the green roof application on the existing building in Belgrade is presented.

Examples of good practice should be used as guidance in forming strategic goals, especially in perceiving the global effects of green roof benefits. However, a strategy can be sustainable only if it is defined in accordance with specific conditions that need to be impartially analyzed.

Therefore, the final objective of initiated research should be the legislation that establishes the standard of calculation for complex green roof systems, which will enable its application and energy efficiency improvement.

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УНАПРЕЂЕЊЕ ЕНЕРГЕТСКЕ ЕФИКАСНОСТИ СТАМБЕНЕ ЗГРАДЕ ПРИМЕНОМ ЗЕЛЕНОГ КРОВА

Резиме: *Унапређење енергетске ефикасности у грађарству у Републици Србији препознато је као подручје које има највећи потенцијал за смањење укупне потрошње енергије, а посредно и за побољшање квалитета живота и комфора у зградама, за заштиту окружења и редукцију емисије штетних гасова, као и за умањење трошкова грејања. Перманентни пораст становништва подстакао је развојни процес урбанизације с различитим последицама по квалитет живота и одрживе будућности. Зелени кровови у урбаним срединама развијених земаља постали су законска обавеза, а политике и програми који заступају озелењавање кровова имају за циљ очување животне средине и обезбеђење одрживог развоја градова. У раду је приказана анализа утицаја зеленог крова на енергетске перформансе постојеће зграде у центру Београда. Један од закључака указује на неопходност израде научних студија и спровођење експерименталних анализа за примену зелених кровова у нашим климатским условима, и да би фокус истраживања требало да буде законска регулатива којом би се успоставила стандардизација прорачуна за системе зелених кровова.*

Кључне речи: *зелени кровови, енергетска ефикасност, урбане средине, законска регулатива, одрживост*