Global Sustainability Challenges
2024; Vol. 2(1): 7-12
https://gsc.unionnikolatesla.edu.rs/index.php/gsc/index
UDC: 712.4:692.425(497.11)
502.3:504.5(497.11)
502.2:711(497.11)
ISSN: 2956-1051 (Online)

Green roofs as a possible solution to air pollution in Belgrade

Vladanka Presburger Ulniković[1, *], Suzana Radojković[2], Violeta Nikolić[1], Lidija Stamenković [3]

[1]Faculty of Ecology and Environmental Protection, University Union-Nikola Tesla, Belgrade, Serbia
[2] Faculty of Science, University of Novi Sad, Department of Biology and Ecology, Trg Dositeja Obradovića 2, Novi Sad, Serbia
3 Academy of Technical-Educational Vocational Studies Niš, Vranje Department, Vranje, Serbia

[*]**Corresponding author:** vladankap@gmail.com

To cite this article:
Presburger-Ulniković, V., Radojković, S., Nikolić, V. and Stamenković, L. (2024). Green roofs as a possible solution to air pollution in Belgrade. *Global sustainability challenges,2*(1), pp. 7-12

Received: Dec 12, 2023; **Revised**: Dec 20, 2023; **Accepted**: Jan 11, 2024

Abstract: In recent decades, due to increasingly climate change, urbanization and industrialization, urban ecology stands out as a special area of ecology and is gaining more and more importance. Cities are specific ecosystems that have a huge role on global climate change and the state of the environment. In facing the challenges of sustainable urbanization encouraged by the current European agenda for research and innovation, in recent decades one of the key roles belongs to green roofs. Although the problem of air pollution in Belgrade is one of the dominant ecological threats it faces, no solutions have been offered for years. Given that the last decade has been characterized by the intensive construction of new buildings, as well as the need to reconstruct existing roofs, this paper highlights the benefit of green roofs as an ideal solution for sustainable urbanization. The similarity of the climatic conditions of the city of Basel, which is the leader in the world in terms of the area of green roofs per inhabitant, and Belgrade, which is at the back in the field of sustainable urban design, was also determined, which is a significant prerequisite for taking over the experiences in the formation of green roofs from Basel to the Belgrade area.

Keywords: green roofs, urban ecology, sustainable urban design, climate change, air pollution

1. Introduction

Green roofs were found on all continents Europe, Asia, Africa, and America through the history. They were found in a hot as well as a cold climate. First green roofs were discovered at Ziggurat of Ancient Mesopotamia (Osmundson T., 1999), from the fourth millennium until 600 BC, located in the courtyard temples planted on pyramid terraces. Famous are hanging gardens of Babylon as probably first botanical gardens in history with many different plants. They were found also in Pompeii, Greece but Zulu Land, among Native Americans and China, India, Indonesia and as well (Abass et al., 2020). Their purpose was to mitigate hot climate and provide a shelter. In a cold climate, green roofs were used as a type of insulation material from prehistoric times. In modern times, they were popular in Russia, Kremlin but also on the roofs of many European cities. In recent decade's researcher have been doing serious research combining different materials and plant for green roofs to improve environment and quality of life in urban areas. It is considered that urban roofs have environmental, social and economic benefits in cities.

The influence of green roofs on climate change is extremely important, they reduce albedo and reflection and affect the status of climate change and reduce the effect of urban hot islands. They absorb excess nitrogen oxides, carbon dioxide and heavy metals, which not only affect climate change but also the quality of life in cities improving air quality. Green roofs a huge impact on reducing urban storm water management pressures, and filtration atmospheric water but they also reduce energy consumption and, noise reduction, they produce oxygen and provide natural habitat for plants and animals. They have an indirect effect on improving the health of the population and their general well-being. The reduced pollution and increased water quality provided by green roofs can reduce health care needs. Green roofs can serve as community hubs, increasing social cohesion, sense of community, association with nature and public safety.

2. Classification/structure of green roofs

Green infrastructure is the network of natural and semi-natural areas, features and green spaces in rural and urban, and terrestrial, freshwater, coastal and marine areas (Jim, 2017). They can be classified into three groups (Catalono et all, 2018):

Figure 1. Typical green roof layers and their hydrological processes (Abuseif, 2023; V8esuviano.& Stovin 2013).

- Intensive with rich vegetation, thicker substrate up to 200 cm, constructed in special places. Intensive green roofs can host trees, shrubs, perennials herbs and lawns but they can be used as parks and recreation places. Maintenance costs are significant because irrigation systems, fertilizers and continuous maintenance are necessary.
- Semi-intensive green roofs can host shrubs, perennial herbs, and lawns on a 12–100 cm thick growing medium. Their vegetation is reduced in number and variety of species so costs of maintenance are also reduced.
- Extensive green roofs are near-natural greened surfaces hosting mosses, succulents, and forbs on a 6–20 cm thick growing medium. The plant species should be local, stress-tolerant, able to regenerate themselves, and propagate easily. The maintenance regime is reduced to the minimum.

There are many types of deer roofs, but they all consist of a vegetation part, a substrate, filter, a drainage layer, protection layer and, root barrier and waterproofing layer. Substrate layer: specially designed for use on green roofs, it provides nutrients and should have the capacity to retain water. Filter layer allows water to pass through, but not the substrate small particulates that could clog the cavities in the drainage layer. Drainage layer must be able to retain water when it rains, while it should also ensure good drainage and aeration of the substrate and roots. Protection layer provides mechanical protection of lower layers, especially for the waterproofing layer. Root barrier and waterproofing layer: intended to protect the building from roots and water (Marin et al, 2023). Figure 1 shows a schematic representation of typical green roof layers and their hydrological processes.

In accordance with the function, financial and climatic conditions, the construction method and plant species are chosen. Mixed plants species have showed better results than a single plant species (Heim A, Lundholm J., 2014). The most commonly used plants *are Ilex verticillata, Physocarpus opulifolius, Amsonia tabernaemontana, Anamone sp. Geranium sp., Echinea purpurea, Sempervivum sp and Sedum sp* as many lichens (Dauda &Alibaba, 2020). It may be possible to reduce nitrogen and phosphorus production by using organotrophs such as *Tipha latifolia* and *Urtica dioica.*

2.1. Acoustic benefits of green roofs

Green roofs compared to roofs without vegetation lead to an increased sound transmission loss of 10 and 20 dB in the low and medium frequency range, while the overall sound reduction index is between 20 dB (at 63 Hz) and 30 dB (at 1 kHz) (António et al. 2018; Galbrun & Scerri, 2017), i.e. the maximum weighted sound reduction index Rv equal to 35 dB.

Sound transmission loss may depend somewhat on the choice of species (Connelly & Hodgson, 2013); Galbrun & Scerri, 2017; Kang et al. 2009).

2.2. Advantages of green roofs in reducing electricity and greenhouse gases

Green roofs can play a small role in reducing CO_2 in the atmosphere in two ways. First, carbon is a major component of plant structures and is naturally sequestered in plant tissues through photosynthesis and into the soil substrate via plant litter and root exudates. Second, as noted above, they reduce energy needs by insulating individual buildings and mitigating the urban heat island. The green roof will eventually reach carbon balance (plant growth = plant decay), but initially this artificial ecosystem will serve as a carbon sink (Bradley Rowe, 2011). The components of a green roof likely have a CO_2 “cost” in terms of the manufacturing process over and above those of a conventional roof (Kosareo & Ries, 2007). There is also a reduction in CO_2 given off from power plants due to the green roof's ability to insulate individual buildings and reduce the urban heat island. Buildings are currently responsible for 39% of global energy related carbon emissions: 28% from operational emissions, from energy needed to heat, cool and power them, and the remaining 11% from materials and construction (World GBC, 2023). According to another source, the built environment is responsible for about 42% of annual global CO_2 emissions (Architecture 2030, 2023). Of those total emissions, construction works are responsible for approximately 27% annually, while the embodied carbon of just four building and infrastructure materials – cement, iron, steel and aluminum – is responsible for an additional 15% annually. In the U.S. buildings are responsible for 38% of carbon dioxide emissions (Neill, 2020). A building with a green roof of 2000 m^2 would lead to electricity savings ranging from 27.2 to 30.7 GJ/year and 9.5 to 38.6 GJ/year of natural gas, depending on the type of climate and the design of the green roof. If national averages of CO_2 produced for electricity production and natural gas combustion are taken into account during the calculation (US EPA, 2007; US EPA, 2008a), electricity and natural gas savings of 2.3-2.6 kg CO_2/m^2 and 0.24-0.97 kg CO_2/m^2 of green roof per year are achieved.

2.3. Public health benefits of green roofs

A green roof can potentially boost citizens' quality of life and indirectly lead to improvements in mental and public health in general. Therefore, focusing on such environmental initiatives can result in a better mood of citizens and be beneficial for society (Mehdi et al., 2021). According to research published earlier this year by the University of East Anglia, access to green spaces can reduce the risk of type II diabetes, cardiovascular disease, premature death, premature birth, stress and high blood pressure. This has significant implications for global health as more than one of these diseases can be found in the World Health Organization's top 10 causes of death (Talbot, 2021).

3. World (EU) example of good practice - a chance for Belgrade

With 5.71 m^2/inhabitant in 2019, the city of Basel in Switzerland has the largest area of green roofs per capita in the world. Based on the outstanding results achieved in the installation of green roofs in the city of Basel, Switzerland, the idea arose that, guided by the experiences of this economically strong and exceptionally organized country, we could implement a part of that project in Belgrade, which has been extremely threatened by poor air quality for years. In addition, at the time of the energy crisis, it is of great interest to reduce energy consumption.

The CH2018 climate scenarios describe how Switzerland's climate could change by the middle of this century and beyond. "Dry summers", "Heavy rainfall", "More hot days" and "Winters without snow" are some of the expected consequences of uncontrolled climate change (NCCS, 2018).

As part of Basel's biodiversity strategy, for the past 15 years, green spaces have been mandatory on all new and retrofitted buildings with flat roofs. Now that this has been made compulsory, more than 1 million square meters of green roofs (Talbot, 2021). Basel's green roof strategy is expected to bring adaptation benefits in the form of lower temperatures and reduced surface runoff. In Europe, about 2 decades ago, several regulations came into force to regulate the design, construction and maintenance of green roofs, of which the Swiss, Italian and especially German ones proved to be the best (Dauda &Alibaba, 2020).

According to the CH2018 climate scenarios for Switzerland, in Basel the number of days with a maximum temperature equal to or above 30°C will increase from the 1981-2010 reference value of 10.5 to 24.7 in 2035, 28 in 2060 and 68.5 in 2085 according to climate scenario RCP8.5. The number of tropical nights (minimum temperature equal to or above 20°C) will increase from 0.6 to 5.9, 15.8 and 40.3 for the years 2035, 2060 and 2085 under RCP8.5.

In the Swiss Plateau region, annual mean precipitation may increase by up to 10% in 2035, 8.4% in 2060, and 10.5% in 2085 under RCP8.5 (although precipitation reductions ranging from -2% to -5.4% may occur for low-end estimates within the same RCP) (NCCS, 2018). Based on these projected changes in climate conditions, green roofs have been found to offer opportunities for combining energy savings, climate change mitigation and adaptation, and biodiversity goals. Reducing energy consumption in buildings and protecting biodiversity were the initial key motivators of this project. It was subsequently pointed out that green roofs also provide the function of adapting to climate change by limiting surface water runoff and reducing urban temperatures (Climate-ADAPT, 2023).

Based on the climatic similarities between the cities of Basel and Belgrade, which is shown in Figures 2 and 3, it can be assumed that in Belgrade we can apply the experience of installing green roofs in Basel.

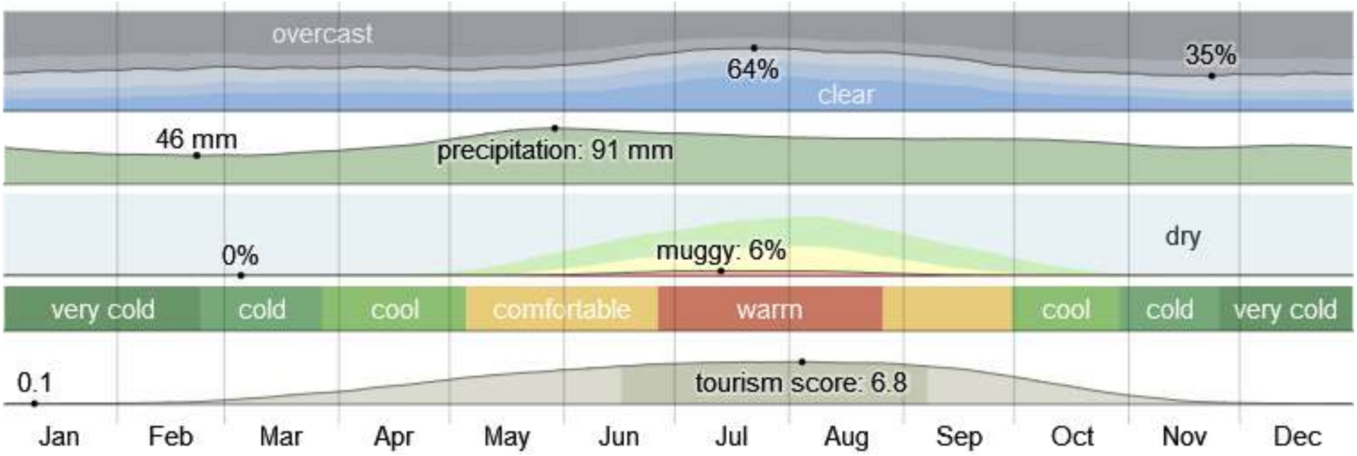

Figure 2. Basel weather by month (Weather Spark (2023a) https://weatherspark.com/y/56447/Average-Weather-in-Basel-Switzerland-Year-Round)

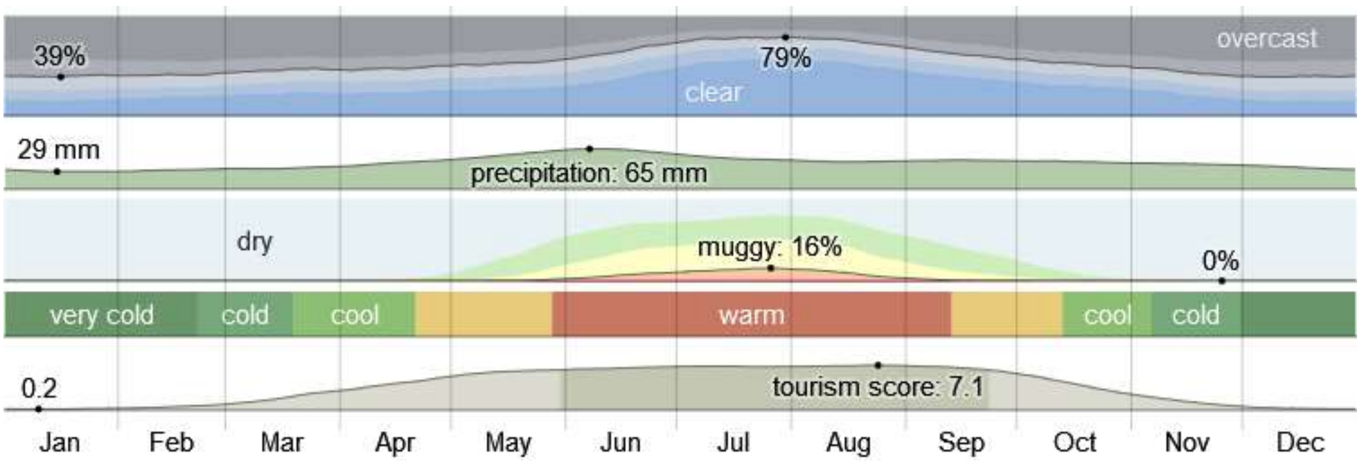

Figure 3. Belgrade weather by month (Weather Spark (2023b) https://weatherspark.com/y/85769/Average-Weather-in-Belgrade-Serbia-Year-Round)

4. Conclusion

The concept of green roofs in the context of the development of urban ecology and urban design can become one of the key factors for the sustainability of cities and their connection with nature. As it was mentioned, they have environmental, economic, and social aspects. Their impact on the environment is consists of pollutant absorption and air filtration, through photosynthesis they reduce carbon dioxide emissions and produce oxygen thereby improving air quality, reduce the noise level, and acting as porous surfaces manage storm water control. Ecological role is providing environment for many birds and ruderal plant species. Economic influence is reflected on increased the life span of the building roof by protecting the roof from thermal, UV radiation fluctuations, and diurnal stress and they are thermal isolators that have both, cooling and preserving energy impact on buildings. Social role means that humans are less stressed in contact with nature, improved air quality would improve human health and life quality and productivity are much higher in increased contact with nature.

Based on all the facts presented, it is clear that there is a need for further research and implement of green roofs with all benefits they provide in urban areas and climate change in general.

References

Abuseif, M. (2023) Exploring Influencing Factors and Innovative Solutions for Sustainable Water Management on Green Roofs: A Systematic Quantitative Review, *Architecture 2023*, *3*(2), 294-327. https://doi.org/10.3390/architecture3020017

António, J., Tadeu, A., Sousa, L., Almeida, R. & Tadeu, D. (2018) Airborne sound insulation of green roofs - conventional versus non-conventional components. *42nd IAHS, World Congress on Housing, Naples, Italy: The Housing for the Dignity of Mankind: Book of abstracts*: 10-13 April 2018 Centro Congressi, University of Naples Federico 2., 12 April 2018 Salone Degli Specchi, Telematic University Pegaso https://www.researchgate.net/publication/337922414_AIRBORNE_SOUND_INSULATION_OF_GREEN_ROOFS_-_CONVENTIONAL_VERSUS_NON-CONVENTIONAL_COMPONENTS

Architecture 2030 (2023) Why the built environment? *Architecture 2030*, *Santa Fe* https://www.architecture2030.org/why-the-built-environment/

Bradley Rowe, D. (2011) Green roofs as a means of pollution abatement, *Environmental Pollution, Volume 159*, (8–9) 2100-2110 https://doi.org/10.1016/j.envpol.2010.10. 029.

A Climate-ADAPT (2023) Case studies - Green roofs in Basel, Switzerland: combining mitigation and adaptation measures. The European Climate Adaptation Platform Climate-ADAPT is a partnership between the European Commission and the European Environment Agency. Published in *Climate-ADAPT* Jun 07 2016 - Last Modified in Climate-ADAPT Dec 12 2023 https://climate-adapt.eea.europa.eu/en/metadata/case-studies/green-roofs-in-basel-switzerland-combining-mitigation-and-adaptation-measures-1/#relevance_anchor

Connelly, M. & Hodgson, M. (2013). Experimental investigation of the sound transmission of vegetated roofs. *Applied Acous*tic 74, 1136-1143.

Abass, F., Ismail, L. H., Wahab, I. A., & Elgadi, A. A. (2020). A Review of Green Roof: Definition, History, Evolution and Functions. *IOP Conference Series: Materials Science and Engineering*, 713, 012048. https://doi.org/10.1088/1757-899x/713/1/012048

Dauda, I., Alibaba, H.Z. (2020) GREEN ROOF BENEFITS, OPPORTUNITIES AND CHALLENGES, *International Journal of Civil and Structural Engineering Research 7*(2), pp: (106-112), Month: October 2019 - March 2020. https://bettercupertino.org/wp-content/uploads/2022/04/isaaiah.pdf

Catalano, C., Laudicina, V. A., Badalucco, L., & Guarino, R. (2018). Some European green roof norms and guidelines through the lens of biodiversity: Do ecoregions and plant traits also matter? *Ecological Engineering 115*, 15–26. https://doi.org/10.1016/j.ecoleng.2018.01.006

Galbrun, L. & Scerri, L. (2017). Sound insulation of lightweight extensive green roofs. *Building and Environment 116*, 130-139.

Heim, A. & Lundhold, J. (2014) Species interactions in green roof vegetation suggest complementary planting mixtures, *Landscape and Urban Planning 130*, October 2014, Pages 125-133

Jim, C.Y. (2017) Green roof evolution through exemplars: Germinal prototypes to modern variants, *Sustainable Cities and Society 35*, August 69–82. https://doi.org/10.1016/j.scs.2017.08.001

Kang, J., Huang, H., Sorrill, J. (2009). Experimental study of the sound insulation of semiextensive green roofs. *Proceedings of Internoise 2009*, Ottawa, Ontario, Canada

Kosareo, L., & Ries, R. (2007). Comparative environmental life cycle assessment of green roofs. *Building and Environment*, *42*(7), 2606–2613. https://doi.org/10.1016/j.buildenv.2006.06.019

Marin C., Bachawati M., Perez G (2023), The impact of green roofs on urban runoff quality: A review, *Urban Forestry & Urban Greening 90*, December 2023, 128138A

Mehdi, R., Nyirumuringa, E., Juyeon, K. & Doo Hwan, K. (2021) Analyzing the Impact of Green Roof Functions on the Citizens' Mental Health in Metropolitan Cities, *Iranian Journal of Public Health 50* (5) May 2021; 900–907. https://doi.org/10.18502/ ijph. v50i5.6107

NCCS (Pub.) 2018: CH2018 - Climate Scenarios for Switzerland. National Centre for Climate Services, Zurich. pp. 11 https://portal-cdn.scnat.ch/asset/62dd6231-91dc-5400-9c5e-83c4770ec55b/CH2018_broschure-4.pdf?b=f401f7ee-b7ab-5aeb-aab4-415eb7e46166&v=5ecfd61e-e9dc-5218-ac34-03d67f64185c_0&s=ZBoLIUXN73HIoL_WeULCfCif0RP6mcjF5LdtPPWan2gtC8LTZfw-VSEjzrfVh9ytUAL38sBHWXhkVsXTud4u73FMzBIcMBKlw0OfGkCrkPLtN1l1icemqVmQ7JBrEgz5ElBuIL2GYIvQRKlOQq3KMFwVSio6RcU1bTEb30kbFhE

Neill, P. (2020) Construction industry accounts for 38% of CO2 emissions, *Environmental Journal* - The environmental news and information site, Macclesfield Cheshire, UK https://environmentjournal.online/features/emissions-from-the-construction-industry-reach-highest-levels/

Osmundson T. (1999) Roof Gardens: History, Design, and Construction (New York: W.W. Norton)

Talbot, H. (2021) How this Swiss city is using green roofs to combat climate change. *Euronews Green*. https://www.euronews.com/green/2021/07/09/how-this-swiss-city-is-using-green-roofs-to-combat-climate-change

US. Environmental Protection Agency, 2007. Inventory of U.S. Greenhouse gas emissions and sinks: fast facts 1990e2005. Conversion Factors to Energy Units (Heat Equivalents) Heat Contents and Carbon Content Coefficients of Various Fuel Types EPA-430-R-07-002. Washington, DC.

U.S. Environmental Protection Agency, 2008a. Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance: Indirect Emissions from Purchases/Sales of Electricity and Steam EPA-430-K-03-006. Washington, DC.

Vesuviano, G.& Stovin, V. A (2013) Generic hydrological model for a green roof drainage layer. *Water Science and Technology 68*, 769–775.

Weather Spark (2023a) https://weatherspark.com/y/56447/Average-Weather-in-Basel-Switzerland-Year-Round

Weather Spark (2023b) https://weatherspark.com/y/85769/Average-Weather-in-Belgrade-Serbia-Year-Round

World GBC (2023) Bringing embodied carbon upfront, World Green Building Council, London, G.Britain. https://worldgbc.org/advancing-net-zero/embodied-carbon/

Zeleni krovovi kao moguće rešenje za zagađenje vazduha u Beogradu

Vladanka Presburger Ulniković[1, *], Suzana Radojković[2], Lidija Stamenković[3]

[1]Fakultet za ekologiju i zaštitu životne sredine, Univerzitet Union-Nikola Tesla, Beograd, Srbija

[2]Prirodno-matematički fakultet Univerziteta u Novom Sadu, Departman za biologiju i ekologiju,Trg Dositeja Obradovića 2, Novi Sad, Srbija

[3]Akademija tehničko-vaspitačkih strukovnih studija Niš – Odsek Vranje, Srbija

*Autor za korespondenciju: vladankap@gmail.com

Apstrakt: Poslednjih decenija, usled sve većih klimatskih promena, urbanizacije i industrijalizacije, urbana ekologija se izdvaja kao posebna oblast ekologije i dobija sve veći značaj. Gradovi su specifični ekosistemi koji imaju ogromnu ulogu u globalnim klimatskim promenama i stanju životne sredine. U suočavanju sa izazovima održive urbanizacije koju podstiče aktuelna evropska agenda za istraživanje i inovacije, poslednjih decenija jedna od ključnih uloga pripada zelenim krovovima. Iako je problem zagađenja vazduha u Beogradu jedna od dominantnih ekoloških pretnji sa kojima se suočava, već godinama nije ponuđeno rešenje. S obzirom na to da je poslednju deceniju karakterisala intenzivna izgradnja novih objekata, kao i potreba za rekonstrukcijom postojećih krovova, u ovom radu se ističu prednosti zelenih krovova kao idealnog rešenja za održivu urbanizaciju. Takođe je utvrđena sličnost klimatskih uslova grada Bazela, koji je vodeći u svetu po površini zelenih krovova po stanovniku, i Beograda, koji je na začelju u oblasti održivog urbanog dizajna, što je značajan preduslov za preuzimanje iskustava u formiranju zelenih krovova Bazela na područje Beograda.

Ključne reči: zeleni krovovi, urbana ekologija, održiv urbani dizajn, klimatske promene, zagađenje vazduha

---