UDC 692.2, 692.4

Adam Ujma, Dr. Eng., Adjunkt, Chief of the Building Physics Laboratory
ORCID ID: https://orcid.org/0000-0001-5331-6808 ***e-mail:*** adam.ujma@pcz.pl

Czestochowa University of Technology, Czestochowa, Poland

PROSPECTS FOR CREATING SURFACES WITH VEGETATION ON BUILDINGS IN POLAND

Abstract. *According to the World Green Building Council, energy demand in buildings will increase double, by 2050. Worldwide, construction and the built environment contribute about 39% of global carbon dioxide (28% from operational emissions, from energy needed to heat, cool and power them, and the remaining 11% from materials and construction) and 50% of the world's resource consumption. Thus, maximising energy efficiency and improving the environment are the main directions of construction development. Both tasks can be solved using green structures that connect living plants with building structures (green roofs, living facades and living interior walls). The data from the main organisations in the branch has been analysed: United Nations, The World Green Building Council, European Parlament and Council, and also Global Alliance for Buildings and Construction. They state the need for green and blue infrastructure, and sustainable urbanisation, incl. decarbonising of buildings and mitigation of urban heat islands. Greening of buildings is a measure to achieve the requirements. In addition, it improves health and well-being or increases biodiversity. Poland has the corresponding norms to stimulate the greening of buildings. The term "biologically active area" is defined as the area with an area arranged in a way that ensures natural vegetation of plants and rainwater retention; such an area also covers 50% of the surface of terraces and flat roofs with a vegetation layer with vegetation and other surfaces (e.g. green facade), providing natural vegetation of plants, with an area of not less than 10 m^2, surface water in this area. Special tax policies give privileges to those who green their building(s). These measures have a good result in spreading green structures, which is proved by the objects represented in the article.*

Keywords: *sustainability; green structures; energy efficiency; biologically active area; water retention.*

https://doi.org/10.32347/2411-4049.2023.2.23-34

1. Introduction

According to the World Green Building Council, energy demand in buildings will increase double [1], by 2050. Worldwide, construction and the built environment contribute about 39% [2] of global carbon dioxide (28% [2] from operational emissions, from the energy needed to heat, cool and power them, and the remaining 11% [2] from materials and construction) and 50% of the world's resource consumption [1].

Cities house more than half of the global population and account for 71...76% [3, 4] of the CO_2 emissions that lie at the heart of the climate crisis.

World Health Organization data show that almost all [5] of the global population (99%) breathe air that exceeds WHO guideline limits and contains high levels of pollutants, with low- and middle-income countries suffering from the highest exposures. Thus, we need to analyse possibilities to improve the energy efficiency and environment of cities. Both tasks can be solved using green structures that connect living plants with building structures.

2. The world experience analysis

The World Green Building Council [6] report points to the need for:

- protection of natural capital and natural resources through investment infrastructure – e.g. prioritising green infrastructure and urban areas;
- enhancing the role of blue and green infrastructure in spatial planning;
- better management of water processes to reduce the depletion of freshwater resources, m.in. through the use of construction wastewater;
- creating larger public and open green and blue areas for both nature and people in cities, reducing the urban heat island effect;
- implementing strategic protection measures – such as flood prevention measures.

A proposal to carry out a comprehensive assessment of CO_2 flows in green infrastructure systems, including buildings with vegetation (green roofs, living facades and living interior walls), over the full life cycle is presented in the diagram in Fig. 1 [7].

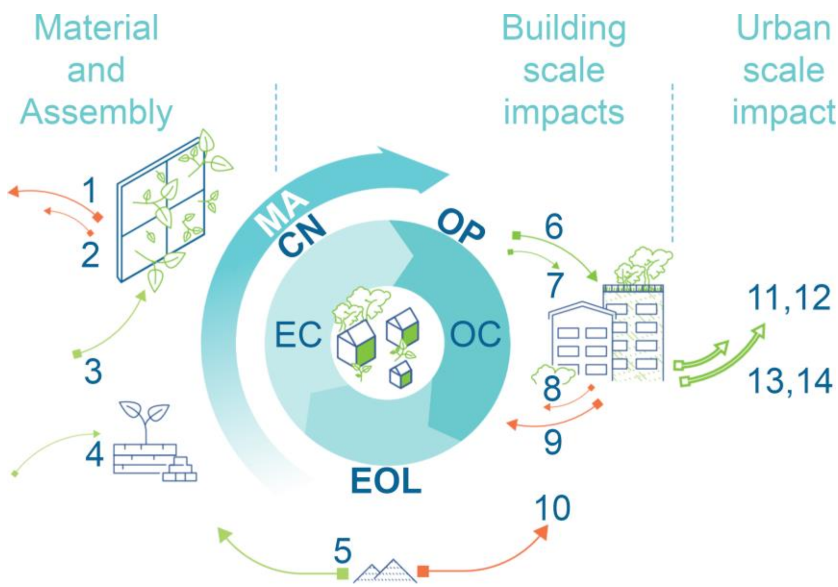

Fig. 1. Green infrastructure and biomaterial systems [7]:
1 – additional structure to carry the weight of soil and water; 2 – additional substrate and material; 3 – extended life of wall/roof material; 4 – use of carbon sequestrating materials and assembly; 5 – use of recycled or biproduct materials in assembly design; 6 – reduction in heating and cooling loads; 7 – reduction in energy of ventilation; 8 – the cost of maintenance; 9 – the cost of water and fertilisers; 10 – emissions from landfill/incineration; 11 – reduction in urban heat islands; 12 – reduction in storm-water infrastructure; 13 – ongoing carbon sequestration from the living system; 14 – carbon offsets from urban agriculture; MA – material assembly; CN – construction; OP – operations; EOL – end of life; EC – embodied carbon; OC – operational carbon

The amount of carbon emissions associated with assemblies and structures should be weighed against the potential for reducing carbon emissions through reduced building cooling and/or heating loads, reduced urban heat island effects, and improved air quality and biodiversity at both a building and urban scale. This quantification of carbon dioxide emissions and reductions should be made by analyzing the building throughout its life cycle. The final result of the assessment will largely depend on climatic conditions, thermal insulation of the building envelope, type and technical parameters of the heating/cooling system, type of fuel or energy used, type of system and plant species. According to some authors, the full reduction of carbon dioxide emissions for some facilities is achieved even after three years. These assessments do not take into account other benefits such as a positive impact on human health and well-being or an increase in biodiversity.

However, since the payback periods for these types of green building systems, taking into account energy costs, are not very encouraging, financial support in the form of incentives and appropriate municipal building codes is necessary to overcome the additional initial costs and concerns about ongoing maintenance costs.

The World Green Building Council report points to the need to design systems for protecting, collecting, and efficiently using natural resources, such as rainwater collection facilities (e.g., wells and water reservoirs, carefully selected to provide sufficient storage space during periods of drought), grey water reuse systems, low-flow amenities and water-saving devices, building green and blue roofs, or installing rain gardens for management rainwater outflow with adaptive and native vegetation [7].

According to data from the United Nations [8] Habitat in 2050 around 68% of humanity will live in cities. At now cities

- occupied only 2% of the Earth's surface;
- consume 78% of energy;
- produce more than 60% of greenhouse gas emissions.

In 2016 the United Nations itself improved the New Urban Agenda [9] to advise countries on their urbanization processes and make cities more habitable, inclusive, healthy, resilient and sustainable. This document draws attention to the challenges of increasing urbanization and suggests possible courses of action. The latest version strengthens the mission of Agenda 2030 to support sustainable urbanization. By 2030, among others, ensure universal access to safe, inclusive and accessible green and public spaces, in particular for women and children, the elderly and people with disabilities [9]. Urban policy measures are to take into account spatial and environmental aspects of revitalization and spatial planning. Poland's participation in the New Urban Agenda [10] concerns i.a. nature-based solutions and the promotion of this approach.

The roadmap for Buildings and Construction 2020-2050 [11] to fully decarbonise buildings throughout their life cycle and to support the development of national or regional strategies and policies sets out short, medium and long-term scopes for action to create a built environment that is carbon-free, efficient and resistant. It includes eight "actions": urban planning, new buildings, existing buildings, construction operations, devices and systems, materials, resilience and clean energy.

The document also guides green and blue infrastructure actions in cities. It contains guidelines with set goals and indicators that cities should achieve by 2030, 2040 and 2050.

In the case of water management, it's necessary to highlight a need to support the increased use of water management technologies, reducing the volume and speed of rainwater run-off, and increasing landscape permeability and rainwater retention. This will increase flood resilience and improve the quality of soil and underground aquifers. Measuring rainwater flow through drain pipes, tanks and drains using smart sensors gives municipal institutions the ability to identify where green infrastructure is needed to improve drainage and mitigate the effects of an urban heat island.

For vegetation, proper landscape and vegetation planning can increase resistance to excess rainwater, reduce the need for heating and cooling, and improve air quality through measures such as green roofs, green walls, trees and parks. In particular, city parks are key to improving the quality of life in cities, cooling cities and acting as sinks of greenhouse gas and other air pollutant emissions. Vegetation measures should give priority to the use of native plant species.

Mitigation of the effects of urban heat islands (UHI) should be sought [11]. Impermeable, devoid of vegetation and dark surfaces in cities tend to generate UHI effects, i.e. higher ambient temperatures. Buildings, streets, parking lots and paved surfaces absorb more heat than damp plant surfaces, which release water vapour and provide shade to cool the surrounding air. To minimize this effect and mitigate extreme heat, cities should set UHI reduction targets and implement a variety of programs to that end. Local authorities may seek to reduce impermeable surfaces, increase the preservation of large canopy volumes, create cool or green roofs and facades, or expand wetlands. Quantitative targets should be included in formal city plans and specify a future target date or annual commitments.

The latest version of the EU EPED (Energy Performance of Buildings Directive (recast)) [12] by the European Parliament and Council points to the need to integrate green infrastructure, such as living roofs and walls, into urban planning and architectural design. This can be an effective tool for adapting to climate change and reducing the harmful effects of climate change in urban areas. Buildings should take into account climatic conditions, including adaptation to climate change through green infrastructure, etc. Member States should encourage the installation of vegetation surfaces that help retain and retain water, thereby reducing urban run-off and improving stormwater management. Improving the good use and adaptation of public space surrounding buildings with elements such as wood, green roofs and facades, and solutions inspired and supported by nature.

Green structures are the universal measure to solve all of the tasks. According to the amendments to the EPBD Directive of 2023 [12], buildings in the European Union must meet the standards of zero-emissions CO_2:

- from 1 January 2026 – newly designed buildings occupied, operated or owned by public authorities;
- from January 1, 2028 – all newly designed buildings;
- by 2050, all buildings (both new and existing).

3. Polish requirements and regulations

The use of partitions of buildings with vegetation (the green roof and green facade) should contribute to achieving the objectives set out in the EPBD.

Biologically active area in the Polish Technical conditions to be met by buildings and their location [13].

According to Polish building regulations, a biologically active area [14] is an area:

- with an area arranged in a way that ensures natural vegetation of plants and rainwater retention;
- such an area also covers 50% of the surface of terraces and flat roofs with a vegetation layer with vegetation and other surfaces (e.g. green facade), providing natural vegetation of plants, with an area of not less than 10 m^2;
- surface water in this area.

Polish building regulations contain requirements for a minimum biologically active area [15]:

1. On building plots intended for multi-family housing, health care buildings (except clinics) and education and upbringing, at least 25% of the plot area should be developed as a biologically active area, if a different percentage does not result from the provisions of the local spatial development plan.

2. The group of multi-family buildings covered by a single building permit provides playgrounds for children and recreational areas accessible to the disabled, according to utility needs, with at least 30% of this area located in a biologically active area, unless separate regulations provide otherwise.

This value is determined as an indicator of the biologically active area of a building plot.

A great deal of information and guidance on how to create buildings and their surroundings soon can be found in the EU guide [16]. There are guidelines for buildings with vegetation. Plants on a green facade can act as a rain cover and help lower air and surface temperatures through evapotranspiration and shading provided by tree crowns. There are several ways to build a green facade (Fig. 2). These can be [16]:

- green ground facades: evergreen or deciduous vines grow on the wall, rooted in the soil next to the facade; self-adjacent plants climb the wall as they grow, directly on the wall or on the frame connected to the wall;
- green facades without roots in the ground: plants grow on special thin layers of a substrate to reduce the weight of the green facade.

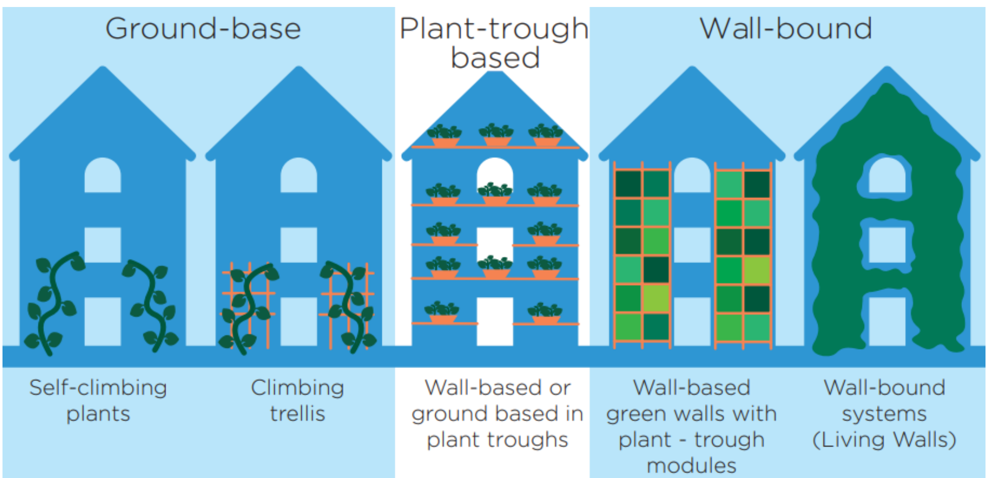

Fig. 2. Schematic drawings of different types of green facades [16]

Green roofs are adapted to heavy rainfall and protect against cold and heat waves. Such properties are primarily possessed by a green retention roof, which ensures an adequate rate of water evaporation and prevents the soil from drying out. The roofs are classified (Fig. 3) as [16]:

- extensive or standard green roofs are green roofs with a relatively thin layer of soil and vegetation. Suitable types of vegetation are succulents or, in the case of shady roofs, a mixture of mosses and herbal plants. Succulents have a high water storage capacity. Photovoltaic panels can be placed on such a roof, which further reduces the temperature on the roof surface. Due to the relatively low weight of roofs with succulents, they can often be laid on existing roofs, up to an angle of about 35°;

- a semi-intensive green roof is a transition between extensive and intensive;
- intensive green roofs have a thicker substrate and plant layer, as well as a greater variety of plants, including shrubs, small trees and nesting sites for birds and bats. Such roofs can contribute to increasing biodiversity.

Height: 6-20 cm Weight: 30-150 kg/m^2 Vegetation: mosses, sedums, herbs & grasses Maintenance: low	Height: 12-25 cm Weight: 120-200 kg/m^2 Vegetation: grasses, herbs and shrubs Maintenance: periodically	Height: 15 cm > 1 m Weight: 180-500 kg/m^2 Vegetation: Lawn, perennials, shrubs & small trees Maintenance: regularly

Fig. 3. Scheme and characteristics of the three basic types of green roofs [16]

A way to encourage the creation of green roofs and facades is property tax reliefs and exemptions introduced in several cities in Poland. Below in Table, there is the number of discounts in property tax, depending on the type of partition with vegetation and the area occupied by it [17]. Tax relief applies primarily to residential buildings.

In Table 1, data from Wroclaw was adopted in 2015 for residential buildings and residential premises. An example of a building with vegetation is from Wroclaw. Extensive green roof of 1600 m^2, intensive roof of 860 m^2, greenery on native land and in pots 360 m^2 (Fig. 4, 5) [18]. Green facade with ivy on the external walls of the National Museum in Wroclaw [19].

In Table, data from Katowice and Kalisz was adopted in 2021. Example of a green roof over the International Congress Centre in Katowice (Fig. 6) [20]. Green facade of the largest Mercure hotel building in Katowice (Fig. 7) [21]. On Fig. 8, there is an example from Kalisz [22].

In Table, data from Czestochowa adopted in 2022, established only for single-family buildings. Example of a green roof over the EXG office building in Czestochowa (Fig. 9) [23]. Green facade created on the external wall of the City Hall building in Czestochowa (Fig. 10) [24].

4. Conclusions

The international experience shows that greening of buildings allows for solving the main problems of cities such as urban heat islands and water resilience. To perform the tasks, the proper normative system is developed. In Poland, in addition, there is a system of tax reliefs which is stimulating the greening that is shown by successfully realized projects.

Table. Property tax reliefs in force in Wroclaw [17]

Type of partition with vegetation	**Percentage of the area occupied by plants**	**Percentage of property tax relief**
Wroclaw		
Green roof in a building up to 5 storeys high	50–80%	50–80%
	80–100%	80–100%
Green roof in a building with a height of more than 5 floors	50–80%	25–40%
	80–100%	40–50%
Vertical garden on the facade	< 30 m^2	20%
	30 m^2 – 45 m^2	25%
	> 45 m^2	50%
Katowice and Kalisz		
Green roof	100%	100% (reduction to 50% in Katowice in buildings with a height of more than 6 storeys)
Green facade (minimum one) with vegetation rooted in the ground	-	
Vertical garden on the facade	50%	
Czestochowa		
Green roof	100%	50%
Green facade (minimum one) with vegetation rooted in the ground	50%	
Vertical garden on the facade	75%	

Fig. 4. Green roof at Botanica Residence in Wroclaw [18]

Fig. 5. Green facade on the building of the National Museum in Wroclaw [19]

Fig. 6. Green roof over the International Congress Centre in Katowice [20]

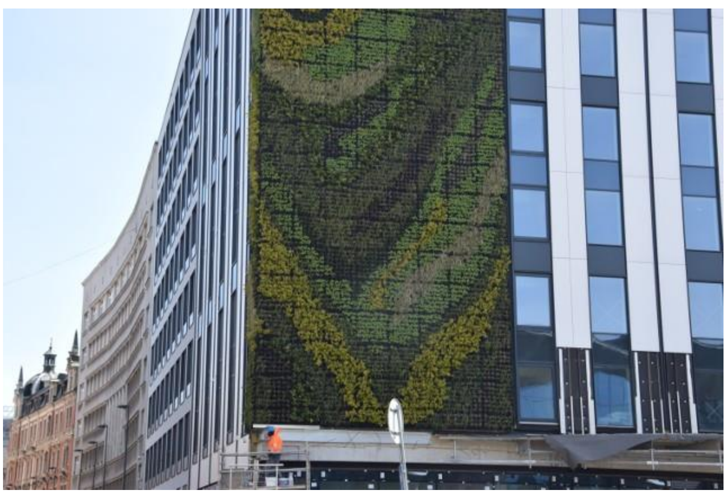

Fig. 7. Green facade on the Mercure hotel building in Katowice [21]

Fig. 8. Green facade on a building located in Kalisz [22]

Fig. 9. Green roof over the EXG office building in Czestochowa [23]

Fig. 10. Green facade created on the external wall of the City Hall building in Czestochowa [24]

REFERENCES

1. The commitment. World Green Building Council. (2023, March 31). Retrieved April 25, 2023, from https://worldgbc.org/thecommitment/
2. Profile of an asia pacific network partner: AGC. World Green Building Council. (2023, January 12). Retrieved April 25, 2023, from https://worldgbc.org/article/profile-of-an-asia-pacific-network-partner-agc/
3. IPCC (2014). Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J., Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_summary-for-policymakers.pdf
4. International Energy Agency. (2021). World Energy Outlook 2021. Paris, France; International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2021
5. World Health Organization. (2022, December 19). Ambient (outdoor) Air Pollution. World Health Organization. Retrieved April 25, 2023, from https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
6. World Green Building Council. (2022). Climate change resilience in the built environment. Principles for adapting to a changing climate. Toronto, Canada; World Green Building Council. https://worldgbc.org/article/climate-change-resilience-in-the-built-environment-guide/
7. United Nations Environment Programme. (2022). 2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. Nairobi, Kenya; United Nations. https://www.unep.org/resources/publication/2022-global-status-report-buildings-and-construction
8. World Economic Forum. (2021). Green Building Principles: The Action Plan for Net-Zero Carbon Buildings. Geneva, Switzerland; World Economic Forum. https://www.weforum.org/reports/green-building-principles-the-action-plan-for-net-zero-carbon-buildings/
9. United Nations. (2017). New Urban Agenda. Quito, Equador; United Nations. https://habitat3.org/wp-content/uploads/NUA-English.pdf
10. Ministry of Investment and Economic Development. (2019). Sustainable urban development in Poland: National urban policy in the context of the 2030 Agenda's Goal 11 and the New Urban Agenda. Warszawa, Poland; Ministry of Investment and Economic Development. https://www.funduszeeuropejskie.gov.pl/media/72570/raport_en_final.pdf
11. Global Alliance for Buildings and Construction. (2020). GlobalABC Roadmap for Buildings and Construction 2020-2050. Towards a zero-emission, efficient, and resilient buildings and construction sector. Paris, France; Global Alliance for Buildings and Construction. https://globalabc.org/sites/default/files/inline-files/GlobalABC_Roadmap_for_Buildings_and_Construction_2020-2050_3.pdf
12. Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings (recast) (2023).
13. Announcement of the Minister of Investment and Development of 8 April 2019 (2019). In: *Journal of Laws*, article no. 1065.
14. Drozd, W. (2019). Problems and benefits of using green roofs in Poland. *IOP Conference Series: Earth and Environmental Science*, 214, 012076. https://doi.org/10.1088/1755-1315/214/1/012076
15. Pawłowska, K., & Jawecki, B. (2021). The determination of priority areas for the construction of green roofs with use of the urban area valorisation method. *Sustainability*, 13(23), 13227. https://doi.org/10.3390/su132313227

16. European Commission, Directorate-General for Climate Action, (2023). EU-level technical guidance on adapting buildings to climate change: best practice guidance, Publications Office of the European Union. https://data.europa.eu/doi/10.2834/585141
17. Person. (2015, July 30). Tax exemptions for green roofs or walls. Wroclaw.pl. Retrieved April 25, 2023, from https://www.wroclaw.pl/en/tax-exemptions-for-green-roofs-or-walls
18. Zielone Dachy. Ogrodowa Pasja. (n.d.). Retrieved April 25, 2023, from http://www.ogrodowapasja.com.pl/nasze-realizacje/zielone-dachy/
19. Wizyta. Muzeum Narodowe we Wrocławiu. (2018, May 21). Retrieved April 25, 2023, from https://mnwr.pl/wizyta/
20. International Congress Centre in Katowice: Conferences, congresses, exhibitions, concerts and sport events. www.mckkatowice.pl. (n.d.). Retrieved April 25, 2023, from https://www.mckkatowice.pl/en/
21. International Congress Centre in Katowice: Conferences, congresses, exhibitions, concerts and sport events. www.mckkatowice.pl. (n.d.). Retrieved April 25, 2023, from https://www.mckkatowice.pl/en/
22. Białas, K. (2021, October 28). Kalisz: Masz Zielony Dach Lub fasadę? Nie Zapłacisz Podatku. Magazyn WhiteMAD - moda, architektura, design w jednym miejscu. Retrieved April 25, 2023, from https://www.whitemad.pl/kalisz-masz-zielony-dach-lub-fasade-nie-zaplacisz-podatku/
23. Postawka-Lech, H. (2020, October 14). Mathematical Precision. EXG's headquarters in Czestochowa from OVO Grąbczewscy Architekci. AiB. Retrieved April 25, 2023, from https://www.architekturaibiznes.pl/en/math-precision,21856.html
24. Zielona ściana ozdobi budynek urzędu W częstochowie. Miasto Zachęca do Tego Kroku Innych właścicieli budynków. Czestochowa Nasze Miasto. (n.d.). Retrieved April 25, 2023, from https://czestochowa.naszemiasto.pl/zielona-sciana-ozdobi-budynek-urzedu-w-czestochowie-miasto/ga/c1-8406889/zd/64286621

The article was received 24.02.2023 and was accepted after revision 10.05.2023

Уйма Адам

ПЕРСПЕКТИВИ СТВОРЕННЯ ОЗЕЛЕНЕНИХ ПОВЕРХОНЬ З РОСЛИННІСТЮ НА БУДІВЛЯХ У ПОЛЬЩІ

Анотація. За даними Всесвітньої ради екологічного будівництва, до 2050 року потреба в енергії в будівлях зросте вдвічі. У всьому світі будівництво та забудовані території утворюють близько 39% глобальних викидів вуглекислого газу (28% від експлуатаційних викидів, енергії, необхідної для опалення, охолодження та живлення, а решта 11% – від матеріалів і будівництва) і 50% світового споживання ресурсів. Таким чином, максимізація енергоефективності та покращення довкілля є основними напрямками розвитку будівництва. Обидві задачі можна вирішити за допомогою зелених конструкцій, які з’єднують живі рослини з будівельними конструкціями (зелені дахи, живі фасади та живі внутрішні стіни). Було проаналізовано дані основних організацій у галузі: ООН, Всесвітньої ради зеленого будівництва, Європейського парламенту та Ради, а також Глобального альянсу будівель і будівництва. Вони констатують необхідність зелено-блакитної інфраструктури, сталої урбанізації, серед іншого декарбонізації будівель та пом'якшення міських теплових островів. Озеленення будівель є заходом для досягнення цих вимог. Крім того, це покращує здоров’я та самопочуття або збільшує біорізноманіття. У Польщі є відповідні норми стимулювання озеленення будівель. Термін «біологічно активна територія» визначається як територія, яку облаштовано таким чином, що забезпечується наявність природної рослинності і затримання дощових стоків; така зона також охоплює 50% поверхні терас і плоских дахів з рослинним шаром та іншими поверхнями (наприклад, зелений фасад), що забезпечують природну рослинність, площею не менше 10 м^2. Спеціальна податкова політика надає пільги власникам зелених будівель. Ці заходи дають хороший результат у розповсюдженні зелених конструкцій, про що свідчать представлені в статті об'єкти.

Ключові слова: стійкість; зелені конструкції; енергоефективність; біологічно активні площі; утримання води.

Стаття надійшла до редакції 24.02.2023 і прийнята до друку після рецензування 10.05.2023

Уйма Адам
доктор інженер, адьюнкт, Завідувач лабораторії будівельної фізики, Ченстоховська Політехніка
Адреса робоча: вул. Академіцка 3, 42-201, Ченстохова, Польща, +48502326061
ORCID ID: https://orcid.org/0000-0001-5331-6808 ***e-mail:*** adam.ujma@pcz.pl