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ELEMENTS OF NATURE-INTEGRATED ARCHITECTURE – RECREATIONAL AREAS ON THE ROOFS USING THE RECUPERATIVE HEAT OF VENTILATION SYSTEMS

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Abstract. The issues of organizing recreation areas at the district level for large and largest cities were studied. These recreation areas are one of the primary tasks in the current conditions of physical and psychological stress on the population of cities. At present, the population of most Ukrainian cities has grown sufficiently, and the number of recreation areas, especially local (district-type) ones, has remained virtually unchanged.

Based on the analysis of architectural and architectural-planning solutions of modern urban development, it is proposed to use the roofs of high-rise buildings for such areas, for which purpose they should be landscaped.

Recreational areas on exploited roofs as an element of nature-integrated architecture are considered. The issue of exploitation of flat roofs, their use as recreational areas, gardens with shrubs or even trees, gazebos, recreation areas, greenhouses or winter gardens is investigated.

To create high-quality conditions for plant growth on roofs and create green areas (winter gardens, greenhouses, greenhouses, etc.), it was proposed to use the low-potential heat of ventilation emissions. For this purpose, the use of both the heat of ventilation emissions directly (for heating the soil) and the use of systems with an intermediate heat carrier, for example, with heat pipes for heating, for example, water for plant irrigation, was considered.

Some problems of utilization of low-potential heat in systems with natural exhaust air movement are considered. Ways to solve urgent problems in this direction are identified.

To increase the temperature potential of ventilation emissions, the possibility of using emissions from the kitchen area and the area of sanitary facilities, the use of heat pumps is proposed, which can increase the thermal potential of ventilation emissions. An installation scheme for increasing the temperature potential of ventilation emissions is proposed. Its advantages and disadvantages are considered.

Keywords: nature-integrated architecture, recreational area, flat roof, green roof, use of low-potential heat.

Introduction. Recreation (latin - recreatio – rest) – is a system of events and functions related to the use of people's time outside of their working hours for recreational, cultural or sports activities in areas prepared for such activities that are located outside their permanent residence.

According to the Law of Ukraine, [1] «recreational areas are areas of land and water space intended for organised mass recreation and tourism». At present, the population of most Ukrainian cities has grown significantly despite martial law, and the number of recreational facilities, especially local (district) ones, has remained virtually unchanged.

Review of recent research and publications. In modern cities, especially large and largest ones, according to the results of studies conducted by Stolberg F.V., Tkachenko T.N., Tkachenko A.A., Rybak O.M., [2-8], the issues of reducing the area for green spaces, organising recreation areas at the district level are quite acute.

The organisation of «green roofs» can help to solve the issue of creating short-term recreation areas for citizens near their place of residence, so the topic of this article is relevant [5, 6].

Based on the analysis of architectural and architectural-planning solutions of modern urban development conducted by Kraynikovets O.V., Shvets V.V., and Shushlyakova O.S. [5-8], it is necessary to point out the tendency of flat roofs in most multi-storey buildings, especially in the so-called "sleeping areas". If earlier a flat roof was considered a fairly "cheap and easy option" for covering a modern building, nowadays a flat roof has completely changed its role – now that its operation has become possible thanks to the latest technologies, a flat roof adds not only additional space but also originality to the design of any building: a flat roof can become a new garden, with shrubs or even trees, a gazebo, a recreation area, a greenhouse or a winter garden, that is, it can be used as a recreational area. With such a seemingly attractive engineering solution, a number of problems arise, which have been considered in some works, for example, by Hetun G.V., Shushlyakov D.O., Serdyuk V.R. [9-11], related to the additional load on building structures, the complexity of organising the installation of these facilities, as well as issues related to the energy and heat supply of such facilities.

The issues of reinforcing building structures, installing objects on roofs and power supply are not covered in this article.

Let's consider the issue of heat supply to such an object as an exploited roof.

At the present stage, the issue of saving energy, especially thermal resources, is quite acute all over the world. In Ukraine, according to studies by Karpalyuk I.T., Shushlyakov D.O., Shulga M.O., Usyk G.A. and others [12-16], about 40% of fuel and energy resources are spent on heating and ventilation of buildings, which is several times higher than in advanced countries. In buildings currently in operation, the share of heat used to heat ventilation air ranges from 30-55%, and in some cases reaches 80%.

In order to save heat energy, modern ventilation systems are equipped with various additional units that allow utilising the heat of the exhaust air, for example, recuperators, heat exchangers of various designs [15, 16]. If at least 10% of the heat of the exhaust air is used to heat the supply air for one 100 m2 apartment, the savings will be more than 400 W per hour. On the scale of cities with hundreds of thousands or millions of people, this will amount to several tens of megawatts.

However, according to the research of scientists (Bozhenko M.F., Khairnasov S.M., Shushlyakov D.O., Molsky S.M. [16-20]), for ventilation systems with natural air movement, which are mainly used to supply existing residential and public buildings with fresh air, such equipment is very difficult to use – the air supply to the premises is not organised, the air enters the premises through infiltration or aeration. In addition, in residential and many public buildings, the use of conventional recuperators is prohibited, as the exhaust air flows into the supply air (during the operation of plate and rotary recuperators).

Purpose and objectives of the study. The purpose of the study is to substantiate the need to create «green roofs» and to identify some of the main ways of providing heat for local (local) recreation areas on the roofs of multi-storey buildings for residents of these buildings, which are associated with the use of low-potential heat from secondary energy resources.

In order to achieve the aim of this study, the following tasks need to be performed:

– to analyse the need for recreation areas at the district level;

– to analyse the main ways of using low-potential heat sources of secondary energy resources for heating «green roof» equipment.

Materials and methods of the study. The study of the organisation of recreational areas on roofs using the recuperative heat of ventilation systems is based on the analysis of scientific sources published in the first decades of the twenty-first century.

The main material of the study was based on the works that reveal the problems of this issue and its main aspects.

Research results. The current growth of the urban population has led to problems in the social, economic and environmental spheres. Urban development has a very high density, which leads to a catastrophic decline in the area of green spaces in the central part of cities, the

disappearance of parks and squares. Recreational areas are disappearing and shrinking not only in city centres, but also in «sleeping areas», as well as suburban green spaces that serve as «green lungs of cities». In other words, such green areas are a source of oxygen for the city and support biodiversity. In addition, they maintain more comfortable thermal and humidity conditions in cities - due to the lack of large areas of green space in central areas, there is a «heat island» effect, when the temperature difference between central urban and suburban areas is about 4...7°C [4]. The factors that negatively affect the population of large cities also include environmental factors, such as air pollution with gaseous and particulate matter from enterprises and transport. This includes not only harmful substances (dust, NO_x, SO_x, CO_2, etc.), but also toxic and carcinogenic emissions (CO, lead, mercury, benzo-α-pyrene, etc.). While the amount of harmful substances is growing and requires a significant increase in the area of 'absorbers', such as plants, there is a significant reduction in green spaces, which leads to a significant deterioration in the environmental condition of cities [7, 14].

Scientists have found that in recent decades there has been a disturbance in the ecological balance caused, to a large extent, by human construction activities, which absorb a significant quantity of resources in the form of building materials and during the operation of buildings and structures. Scientists recognise the reduction of natural space, especially in highly urbanised environments, as one of the irreparable losses caused by human construction expansion. The rapid pace of urbanisation and the construction of new residential areas are leading to an increasing reduction in the landscape component of cities, and natural areas are being built up in the largest and most populous cities in the world, including in Ukrainian cities [8]. This trend is especially true for settlements with high land values.

The development of large and largest cities disrupts and changes the relationship between humans (city residents) and the environment. This connection is being replaced by regulatory documents that establish a standardised area of greenery per person. The emotional and spiritual component of nature is removed, and only plantings grass, bushes and trees remain.

A one-sided, consumerist understanding of green spaces in the city completely drowns out the «human-nature» connection. This process leads to the fact that, even if there is sufficient green space, people do not feel comfortable in the city.

As a result, the problem of finding such natural forms that would preserve the connection between nature and people living in the urban environment, would satisfy their need for green spaces, their aesthetic needs and, at the same time, would not contradict the development of the urban environment, is becoming more acute.

Currently, there is a need to introduce «wildlife» into the urban environment. Elements of nature-integrated architecture and their inclusion in the structure of residential and public buildings in large cities will help to solve this problem. The most popular method of integrating the natural component into architectural objects is the installation of green roofs and equipment on the roofs of recreational areas. This is a way to solve the lack of greenery in the urban environment, it provides an opportunity to incorporate the natural component into buildings, to saturate the modern city with greenery without trying to find additional territorial resources. In modern cities with a high population density, greenery is increasingly developing in three dimensions, with rooftop recreation centres being used more and more often every year and occupying a significant place in shaping the architectural environment of cities and urban landscapes, and becoming a means of humanising the urban environment. At the same time, as a form of three-dimensional landscaping, they are called the «fifth facade of the city».

The «fifth facade of the city» is a relevant concept that involves another significant part of the urban environment – the roof of the building – in the development of the architectural urban environment. Such elements of nature-integrated architecture do not take up land, effectively increase the area of urban greenery and improve the environmental situation of the city.

Therefore, the creation of recreational areas on exploited green roofs can be an answer to the problems of modern cities – the lack of a natural component in the urban environment, the deterioration of the ecological state of cities, the deterioration of the mental and physical health of

residents, the loss of architectural expressiveness and the originality of urban development.

Also, rooftop recreational areas have the ability to be fully incorporated into the green infrastructure of urban areas, to serve as one of the structural elements in the green urban framework – a strategically planned network of natural areas in the city.

There are many examples in the world of a harmonious combination of architecture and the natural component of environment (Fig. 1), and the creation of such objects in buildings of various functional purposes.

Residential buildings

The project of the residential complex "Multilayer City", by arch. Jacques Ferrier Architecture, Chartier Dalix and SLA Architects, Paris, France

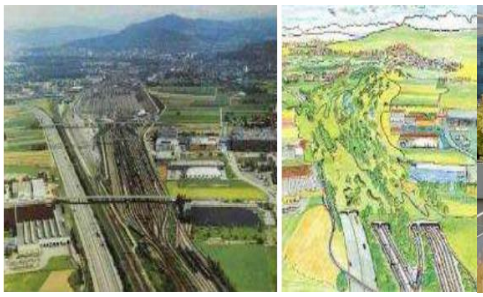
Multifunctional buildings

CapitaSpring Building (Architectural studios BIG and Carlo Ratti Associati), Singapore

Educational and scientific institutions

Schlumberger research laboratory buildings, USA

Transport infrastructure facilities



The project of the Limmattal marshalling yard, arch. P. Vetsch, Switzerland

Administrative facilities

Complex of administrative buildings – Sejong City Hall (Seoul, South Korea)

Administrative facilities

Park on the roof of a shopping centre, (Wuhan, China)

Fig. 1. Formation of recreational areas on roofs in architectural objects

A number of problems characterise the condition, location and functioning of the recreational facilities of Ukrainian cities:

– insufficiently high level of organisation and architectural and planning solutions of the existing system of recreational areas of cities;

– lack of green areas of mass accessibility in the central districts of the city;

– lack of recreational facilities in residential areas, in areas of historical buildings, near transport hubs;

– lack of recreational facilities in areas of dense residential development;

– disorganisation of pedestrian and transport links between the territories of parks of district

significance and the green framework of cities;

– lack of recreational facilities at the level of residential units (apartments).

And these problems should be solved at all hierarchical levels of the green urban framework: at the city-wide level, at the level of the residential district, at the level of the central city district, at the level of the residential unit.

The system of green urban framework and green infrastructure connectivity in urban areas is formed gradually by creating continuous strips of natural habitats. And in this sense, rooftop recreational areas should be considered as an element of the urban level, which includes parks and urban forestry, as well as green roofs, walls and other techniques to reduce energy consumption and stormwater runoff [3].

Creating a «green roof», placing recreational areas, gardens and parks on the roof is a fairly new trend in Ukraine. At the same time, the use of such solutions has already become the norm in many European countries and the United States. Some countries, such as the USA, the UK, and Germany, support the development and implementation of recreational areas on roofs at the state level.

The arrangement of operated «green» roofs is usually divided into three main types depending on the method of greening used:

– with intensive landscaping;

– with semi-intensive landscaping;

– with extensive landscaping.

Each has its own characteristics and application possibilities, depending on the urban planning conditions and the structural and volumetric-spatial features of the building. Intensive landscaping is used to create full-fledged recreational areas on the roofs. It should include the planting of trees and shrubs, perennial herbaceous plants, and the creation of various types of lawns. The plantings can be placed both on the same level and on different levels of the roof area using geoplastic relief techniques.

An example of one of the first residential buildings in Ukraine with a rooftop park is the Royal Tower residential building in Kyiv (Fig. 2). This decision was made due to the lack of a landscaped adjacent territory. In this case, it was decided to equip it on the roof. The project is based on the idea of creating a park with spreading crowns of mature trees and various varieties of shrubs, with playgrounds and walking paths where residents can relax and at the same time look at the breathtaking panoramas of the capital's centre. In this way, the architects compensated for the lack of land and natural elements in the area.

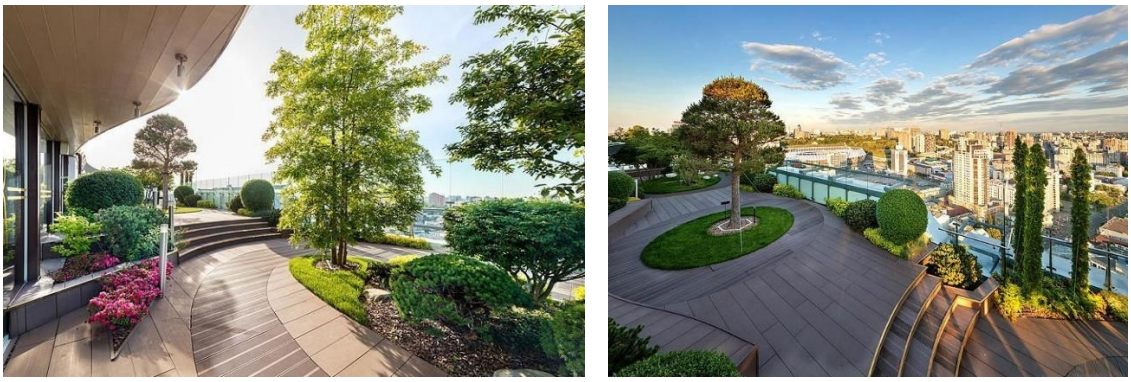


Fig. 2. Recreational space on a residential building. Park on the 31st floor of the Royal Tower building in Kyiv (Ukraine)

Different energy sources can be used to supply green roofs with energy. However, from the point of view of reducing carbon fuel consumption, it is more efficient to use «secondary energy», for example, the heat of ventilation air removed from buildings.

One of the most promising areas in the technique of low-potential heat recovery in ventilation systems, which has not been developed to date, is the use of heat exchangers on heat pipes [18-20].

A heat pipe (Fig. 3) is a circuit with a heat carrier in which phase transitions of the heat carrier from liquid to gaseous state and back are carried out in a cyclical manner [20].

The heat exchanger will consist of several rows of heat pipes installed in a staggered or corridor pattern. One end of the heat pipes will be installed in the exhaust air duct (evaporation zone), the other end will be installed in the supply air duct (condensation area).

The advantage of such a heat exchanger is the high efficiency of heat exchange even with a slight temperature difference between the supply and exhaust air, the absence of air flow from one air duct to another, and the ability to move the supply and exhaust air ducts 2-3 m apart.

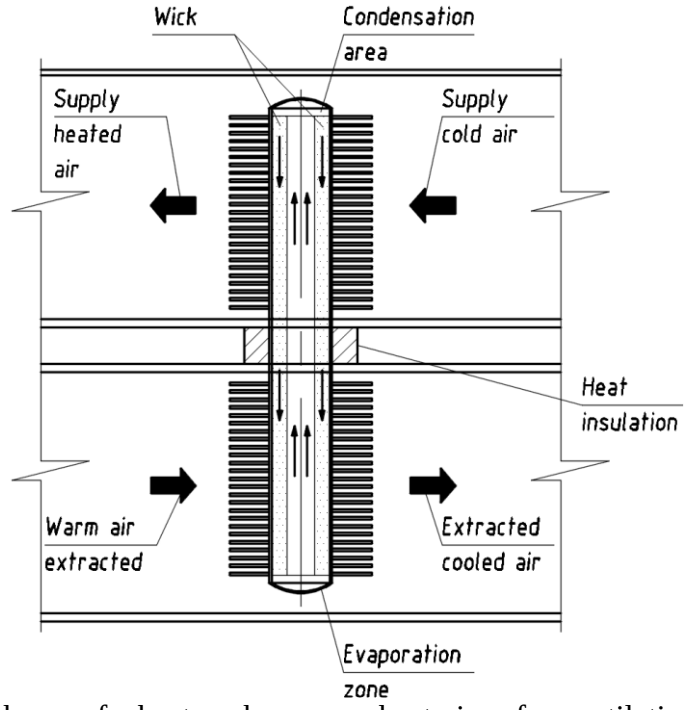


Fig. 3. Scheme of a heat exchanger on heat pipes for ventilation systems

At the same time, it is quite possible to use the heat of the exhaust air if water is used on the "cold side" instead of air. With a recovery of 10-15°C from the exhaust air, it is virtually impossible to heat the water by more than 3-6°C without using additional equipment. Such water with a temperature (in the cold period of 8-10°C) can be used to irrigate the plant carpet on the roof (Fig. 4).

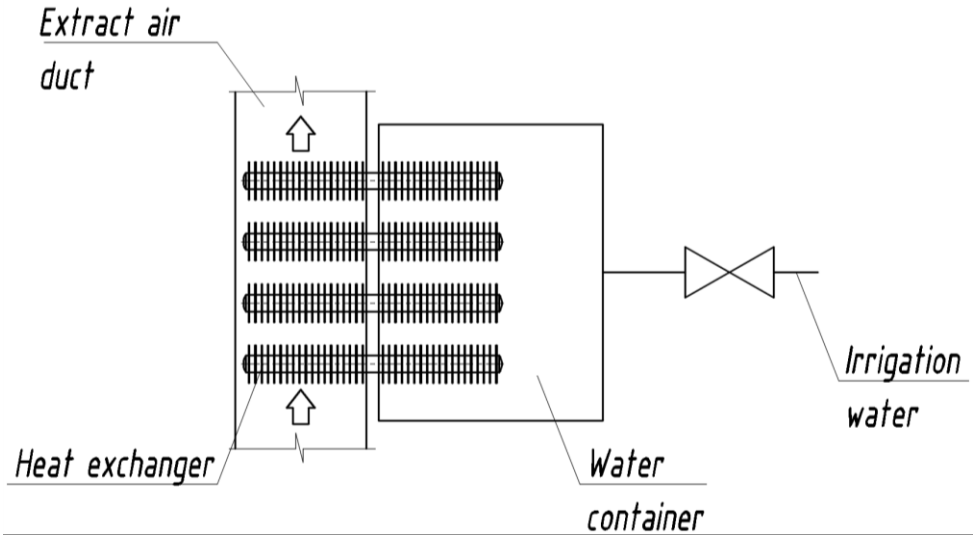


Fig. 4. Utilization of exhaust air heat to heat water for irrigation

The simplest method of heating the soil is to use channels laid under the soil. The air exhausted from the apartments will pass through these channels, maintaining a positive ground temperature. This system cannot be used as a heating system for greenhouses or winter gardens, as the temperature potential of the air in ventilation systems is, as mentioned above, quite low. However, such a system (provided that the horizontal ducts are short and have a minimum number of turns) will allow the soil temperature to be kept positive during the cold season.

A significant disadvantage of this system is that the heat of the air removed from the sanitary facilities [17] cannot be used (according to the regulations [22]) to avoid unpleasant odours entering the recreational area.

It is possible to include a heat pump instead of a heat exchanger on heat pipes in the utilization scheme [21]. This will significantly increase the capital cost of the roof, but such a system (Fig. 5) will allow the heat extracted from the exhaust air to be used for heating (by increasing the temperature potential) of a winter garden or closed gazebos on the roof.

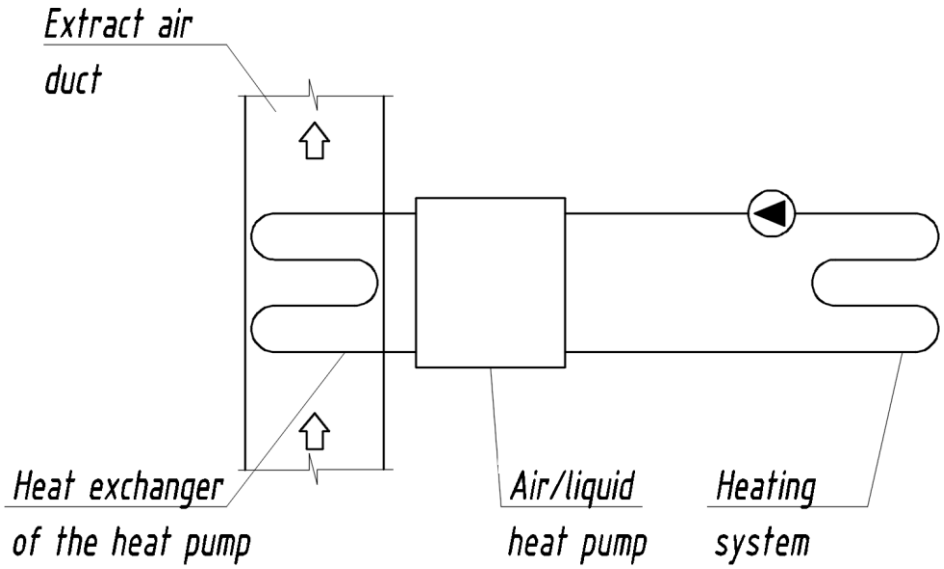


Fig. 5. Utilizations of exhaust air heat for the heating needs of a winter garden or gazebos

Conclusions. The arrangement of exploited roofs will make it possible to organise recreational areas in the «sleeping areas» of large cities, and the utilisation of ventilation air heat will partially solve the issue of heat supply to these facilities.

In our country, in the post-war period, the development of such a trend in nature-integrated architecture as the creation of recreational areas on the exploited roofs of architectural objects of various functional purposes will also become more relevant. This will have great potential in creating a comfortable urban environment and replenishing the natural component of urban areas.

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ЕЛЕМЕНТИ ПРИРОДОІНТЕГРОВАНОЇ АРХІТЕКТУРИ – РЕКРЕАЦІЙНІ ЗОНИ НА ПОКРІВЛЯХ ІЗ ВИКОРИСТАННЯМ РЕКУПЕРАТИВНОЇ ТЕПЛОТИ СИСТЕМ ВЕНТИЛЯЦІЇ

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Анотація. Досліджувались питання організації зон рекреації районного рівня для великих й найбільших міст. Ці зони відпочинку є одним із першорядних завдань у сучасних умовах фізичного та психологічного навантаження на населення міст. На цей час кількість населення більшості міст України достатньо зросла, а кількість місць відпочинку, особливо місцевого (районного типу) залишилась практично не змінною.

На підставі аналізу архітектурних та архітектурно-планувальних рішень сучасної міської забудови запропоновано для таких зон використовувати покрівлі багатоповерхівок, для чого провести їх озеленення.

Розглянуті рекреаційні зони на експлуатованих покрівлях, як елемент природоінтегрованої архітектури. Досліджено питання експлуатації пласких покрівель, використання їх у якості рекреаційних зон, саду із чагарниками чи навіть деревами, альтанками, майданчиками для відпочинку, теплицями чи зимовими садами.

Для створення якісних умов росту рослин на покрівлях, створення зелених зон (зимових садів, теплиць, оранжерей тощо) було запропоновано використовувати низькопотенційну теплоту вентиляційних викидів. Для цього було розглянуто використання, як безпосередньо теплоти вентиляційних викидів (для прогріву ґрунту), так й використання систем з проміжним теплоносієм, наприклад, з тепловими трубами для підігріву, наприклад, води для поливу рослин.

Розглянуто деякі проблеми утилізації низькопотенційної теплоти у системах з природним спонуканням руху витяжного повітря та виявлено шляхи для рішення нагальних проблем у цьому напрямку.

Для збільшення температурного потенціалу вентиляційних викидів, можливості використання викидів з кухонної зони та зони санітарних вузлів, запропоновано використання теплових насосів, які можуть збільшувати тепловий потенціал вентиляційних викидів. Запропоновано схему установки для підвищення температурного потенціалу вентиляційних викидів. Розглянуто її позитивні сторони, та недоліки.

Ключові слова: природоінтегрована архітектура, рекреаційна зона, плоска покрівля, зелена покрівля, використання низькопотенційної теплоти.

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