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Integrated greenhouse module as one of the promising areas for the development of greenhouse structures

Abstract. The study addresses the issue of greenhouse structures in Ukraine, most of which, after an active period of construction (mid-20th century to the second half), have reached their limit in architectural-constructional and innovation-technological aspects, as contemporary scientific and practical papers in the field of architecture and greenhouse design are almost absent. The purpose of this study is to identify promising areas for the development of greenhouse structures, establish types of integrated greenhouse modules, and formulate basic recommendations for their organisation. The research methodology consists of three stages (preparatory, research and synthesis) using methods such as analysis of literary and scientific sources, terminological clarification of concepts, logical analysis, critical and comparative analysis, graph-analytical method, generalisation, induction, hypothesis and forecasting. As a result of examining examples of global experience, five types of integration of greenhouse modules into the structure of buildings and structures of various typologies were identified: “greenhouse module – open atrium”, the concept of which is to create a green module in the space of an open atrium to organise a cultural and aesthetic point of attraction; “greenhouse module – closed atrium”, which is formed in the space of a separate, closed atrium that separates different functional blocks and creates a buffer zone for employees of the institution; “greenhouse module – ‘green’ rooms”, which are implemented in those functional blocks that, to the extent of their specificity, require psychological and unloading rooms, rooms for emotional relaxation and meditation; “greenhouse module – floor”, which serves as a buffer floor between different functional blocks to create a comfortable environmental and social background for people in the working environment; “greenhouse module – entire building” is the rarest type, which increases the level of efficiency, motivation and creativity. An analysis of individual structures allowed identifying the following recommendations for integrating greenhouse modules: greenhouse modules should be incorporated in the design stage; medical, botanical and aesthetic aspects should be considered; carefully select the assortment of plants; proper care of plants will ensure the longevity of the module; the greenhouse module should address the set tasks. The practical value of this study

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lies in the fact that the results can be used to create recommendations and methodological guidelines for designing greenhouse modules

Keywords: ecological design; modern public buildings; interior phytodecoration; integrated greenhouse; phytodesign; enclosed space

INTRODUCTION

The development and evolution of greenhouse structures are the result of complex changes in social-demographic, recreational-leisure and ecological needs of the population. A greenhouse structure combines botany, ecology, architecture and engineering in its concept, making interdisciplinary connections crucial in this field. There is a significant lack of research in the field of architecture concerning greenhouses in the Ukrainian scientific community, leading to a prolonged pause in the design and construction of new greenhouses, and unsuccessful attempts at the reconstruction and restoration of historical greenhouses.

M. Davydenko (2021) emphasised the significance of the activity of the academician of the NASU (National Academy of Sciences of Ukraine), Doctor of Biological Sciences, Professor A.M. Grodzinsky at the international level. Research conducted by A.M. Grodzinsky, allowed him to develop new approaches to solving problems of introduction and acclimatisation of plants, green construction, park science and allelopathy (chemical interaction of plants). These studies can be considered a foundation for the further active development of botanical gardens, including greenhouses and greenhouse complexes, focusing on the introduction and acclimatization of tropical plants in closed soil conditions. The author demonstrated that A.M. Grodzinsky's main achievements, serving as the basis for incorporating plants into the interior structure, include formulating a series of fundamental principles of phytodesign recognised by Ukrainian and global science: the aesthetic-psychological impact of plants on humans is achieved through the beauty of form and colour; improving the living environment, disinfecting and enhancing the environmental health are achieved through airborne phytoncides.

N. Hnilusha (2022) in his methodological recommendations for the discipline "Phytodesign" highlighted the specific contributions made by students and followers of A.M. Grodzynskyi in this field. For example, M. Schleiden & A. Regel described the influence of various plant groups on humans; V.V. Snizhko developed typical compositional-plant groupings for various interiors; I.P. Hornytska identified 30 forms of tropical and subtropical plants based on their biological and ecological characteristics, which proved to be very promising for interior phytodesign. The methodological recommendations reveal the features of typological application of phytodesign, provide a range of plants with prospects for use in phytocompositions, and provide guidelines for creating and regulating the necessary climate.

N. Merzhievskay & A. Sokolova (2021) addressed the terminology of cultivation structures, identified historical stages of development and evolution of closed ground types, and proposed a classification of greenhouse structures based on such criteria as the construction period, type of placement, role in shaping the urban environment, landscape structure, functional purpose, integration into other structures by typology, architectural-compositional solution, structural scheme, material of the load-bearing structure, material of the covering, ability to simulate climate and heating source.

V. Novosad *et al.* (2021) investigated the question of recreational plant resistance in an urbanised environment. They examined terms such as "resistance", "adaptation", "recreational resistance" and others. Based on biomorphological analysis, the authors proposed an algorithm for differentiating recreational resistance, through which marker signs of changes at different levels of plant formation and development can be identified. These studies were conducted concerning plants in natural environments, but such an algorithm can also be applied to plants in closed soil conditions, such as in greenhouses or hothouses.

O. Strashok & A. Morozko (2021) established that interior phytodecoration is an essential component of creating a comfortable environment for employees in various institutions. They investigated the phytodecoration of the interior of the Cabinet of Ministers of Ukraine, the history of which began around 2003. After the reconstruction of the Cabinet of Ministers' halls, specialists in landscaping and phytodecoration formed the first phytocompositions for decorating recreation rooms, entrance and transit zones, meeting rooms, press and journalism rooms, and the small hall of the building. Researchers proposed seven new compositions using an expanded range of tropical and subtropical plants, created with specialised software Real Time Landscaping Architect.

A. Dzyba & K. Saveliev (2023) identified the importance and necessity of cultural ecosystem services of parks during the war in Ukraine due to the emotional-psychological vulnerability of people. The conducted survey helped establish that a large number of respondents seek greater interaction with elements of park improvement and more areas for socio-cultural enrichment. D. Saadi *et al.* (2021) found that green environments have a strong restorative impact on human psychological and physiological parameters, depending on the function, aesthetics and quality of park plantings.



The purpose of the study was to identify prospective areas for the development of designing, constructing, and restoring greenhouses and greenhouse structures. The analysis of contemporary global architectural experience helped identify the specificity of modern public objects, incorporating “green” modules with different functional contents into their structure. The diversity of such modules prompted the derivation of types of integrated modules and the formulation of recommendations for their implementation.

MATERIALS AND METHODS

This study consisted of three stages: preparatory, research, and synthesis. In the first stage, the preparatory stage, the multi-level nature of the problem and the relevance of the study were determined. During the search for examples of greenhouses and greenhouse structures, mostly in the USA, European countries and Asia, using the method of logical analysis, it was disclosed that new greenhouses appear less frequently with a new philosophy of functioning, proposing more interaction with society and active participation in the ecological aspect. It was also found that increasingly, “green” modules are incorporated in new modern public structures. The analysis of literary and scientific sources, combined with the method of terminological clarification of concepts, helped clarify terms such as “winter garden”, “phytodesign”, “phytmodule” and combining them to formulate the term “integrated greenhouse module”.

In the second stage of the study, the exploratory stage, it was necessary to identify the relevance of introducing plants into the interior spaces of public buildings and structures. This involved applying the methods of critical and comparative analysis. Considering the multifaceted nature of the issues, an interdisciplinary research method was applied to determine the positive components of this integration on architectural-aesthetic, botanical, psychological and medical levels concerning humans. The research of A. Grodzinsky *et al.* (1989) was utilised for botanical and psychological aspects; N. Merzhievskaya & A. Sokolova (2021) – for architectural-aesthetic aspects; and the report from the U.S. Environmental Protection Agency (1989) – for ecological and medical perspectives. After clarifying the prerequisites and scientific foundation using critical and comparative analysis methods and the method of generalisation, a sample of objects was created based on criteria such as geographical diversity of locations, public purpose of the structure, a pronounced “green module”, variability of the module’s functional range, diversity in the structural scheme of the module and modern architectural-aesthetic solutions.

In the third stage, the synthesis stage, using the method of generalisation and a combination of induction and deduction methods, five types of integration of greenhouse modules into the structure of public buildings were derived, and five general recommendations for

their organisation were proposed. A graphic analysis was conducted on ten selected objects (two for each type of integration) using Archicad 24 and Adobe Photoshop 18, outlining the building’s contour, greenhouse module contour, main entrances/exits, and functional content of adjacent blocks. Graphic materials from almost all projects were sourced from a large electronic gallery of modern architectural objects – Achdaily. Applying the method of intuitive forecasting revealed prospective areas for the development of greenhouse structures, emphasising integrated greenhouse modules, particularly as the percentage of construction increases each year.

RESULTS AND DISCUSSION

The history of the development and evolution of greenhouses traces back to Ancient Egypt, and modern greenhouses have fundamentally changed compared to their early typological representatives. The shift in social needs has altered not only architectural planning decisions but also the philosophical significance of greenhouses in the city structure. In the contemporary world, greenhouse objects have a multifunctional, adaptive and innovative character (Merzhievskaya & Sokolova, 2021). The experience of designing greenhouse structures in Ukraine has also flourished, mainly driven by active development in the botanical-breeding field. This precondition has shaped the main feature of Ukrainian greenhouses – their location on the territory of botanical gardens, which are specialised higher educational institutions. In Ukraine, there are approximately 33 botanical gardens, with around twenty of them having individual greenhouses or greenhouse complexes. These structures serve multiple functions but are primarily oriented towards scientific, educational, recreational-leisure and ecological activities (Nature Reserve..., 2021).

Analysing the global experience of designing greenhouses and greenhouse structures, one can note a significant variability manifested in the restoration of the original appearance of historical greenhouses, the restoration of greenhouses with a change or adjustment of function, the construction of new ecological clusters, the construction of mobile greenhouse modules to enhance the aesthetics of the urban landscape, and the integration of greenhouse modules into the structure of various buildings. Considering the characteristics of Ukrainian and global architectural experience, greenhouse structures, both modern and preserved from previous eras, can be divided into four conditional groups in terms of their aesthetic-cultural significance in the city’s life.

The first group includes architectural and historical monument greenhouses. They reflect the best examples of architectural, structural, technological and landscape-floristic professionalism of the time. In terms of their socio-economic significance, such greenhouse objects currently bear the burden of museum facilities, characterised by a more demonstrative nature with minimal interaction with visitors.



The second group comprises contemporary greenhouses that reflect the incredible industrial development of the city and the country. Typically, these are large multifunctional complexes utilising state-of-the-art construction and climatic technologies. Greenhouse complexes, such as ecological clusters, where recreational activities are organised for all age groups, cease to be museum-like; they stand out for maximum interaction with visitors.

The third group includes integrated greenhouses harmoniously incorporated into the structure of public, specialised and residential buildings, creating a more comfortable, psychologically friendly, ecologically healthy and inspiring environment. This type of greenhouse is highly interactive with people, designed to improve their conditions for temporary or permanent stays.

The fourth group consists of greenhouse installations representing stationary or temporary compact-sized greenhouses of any configuration and construction scheme. Greenhouse installations serve as elements of public space in the urban environment, on streets, squares, recreational areas, or courtyard spaces. Among the main tasks faced by elements of landscape improvement, including greenhouse installations, are functional (ensuring the optimal nature of the territory's function realisation), aesthetic (possessing individuality and imagery) and ecological (establishing a possible balance between natural and anthropogenic components of the environment) (Tiurikova *et al.*, 2021). As of 2023, this type is not widespread but is actively applied in cities with poor air quality as a station for air purification and recreation.

The issue of actively integrating plants into the interior space of public buildings addresses a range of issues related to improving working conditions at ecological and medical levels, beyond the artistic and aesthetic aspect. In the era of the global environmental crisis, the problem of environmental pollution with xenobiotics becomes increasingly urgent. There is a pressing need to improve the state of atmospheric air in cities, as pollutant levels in indoor air are ten times higher compared to open urban areas (Vazquez & Adams, 2014). Interior greening goes beyond aesthetics; it involves the use of plants to disinfect indoor air from pathogenic microflora, purify the air from industrial dust and gases, and address issues such as air ionization, humidity, sound absorption, and, most importantly, oxygen enrichment. Therefore, the tasks of phytodesign are diverse and extend beyond simple greening (Snizhko & Kharitonova, 2006). Given that people spend 80-90% of their time indoors, the issue of improving indoor environments, particularly from medical and ecological perspectives, remains relevant (U.S. Environmental..., 1989).

Interior greening is one way to enhance public spaces and improve working conditions for people. Modern requirements for phytodesign include careful selection of predominantly decorative tropical and subtropical plants

and an understanding of their ability to thrive in the extreme conditions of interiors (Grodzinsky *et al.*, 1989). Preserving the decorative qualities of tropical and subtropical plants in the interior structure is only possible by creating conditions such as proper orientation of the building to light, adequate illumination, balance of humidity and dryness in the air, creating a favourable microclimate inside. As of 2023, the practice of introducing green modules after constructing buildings and placing equipment is still prevalent, especially in Ukraine. This practice makes the spaces less suitable for plants, hindering correct, long-term maintenance and increasing care costs. Therefore, the key to the longevity of active greening is to plan the specifics of their placement during the design stage.

After analysing global experience, the following types of greenhouse module integration into the structure of buildings of various typologies were identified:

1. Greenhouse module – open atrium;
2. Greenhouse module – closed atrium;
3. Greenhouse module – “green” room;
4. Greenhouse module – floor;
5. Greenhouse module – entire building

The variability of global design and reconstruction experience for greenhouses and greenhouse structures allows for a more detailed analysis of each of the above types of integrated greenhouse modules, using specific projects as examples.

The first type of integration – “greenhouse module – open atrium” – represents a space under an atrium with active greening. It can include individual plants in movable or stationary containers, the creation of floor compositions, rock gardens, vertical greening on pergola structures and additional greening of the corridor on each floor of the atrium space. Any public or residential buildings with an atrium are suitable for implementation. Simulating a climate for plants in an atrium module is not envisaged; only intermittent spraying is possible. Therefore, a judicious selection of plants capable of enduring extreme conditions is necessary. V. Monarch (2020) noted that it is important to consider the fact that plants grown indoors are brought from different countries and each type has its characteristic temperature regime based on its natural origin. Therefore, it follows that in one greenhouse module, plants from the same climatic zones should be arranged.

The researchers suggest that this is the most common type, as it can be arranged even after the construction of the building. As an example, the Jakarta hotel project on Java Island, Amsterdam, Netherlands, in 2018, was chosen. The hotel's green atrium is an undeniable focal point of the structure both architecturally and functionally. On the first floor, this module has quiet relaxation areas, a waiting area near the vestibule and adjoins the open restaurant area, creating a unique tropical atmosphere. The hotel rooms on the upper floors open into local “jungles”, providing temperature and humidity regulation (Fig. 1).



TYPES OF ORANGERY MODULES INTEGRATED INTO THE STRUCTURE OF PUBLIC BUILDINGS



Figure 1. The first type of integration – “Greenhouse module – open atrium”

Source: developed by the authors based on ArchDaily (2018; 2021c)

The expansion project of Helsinki Airport, Vantaa, Finland, in 2021, by the architectural bureau ALA Architects (lead architects – Juho Grönholm, Antti Nousjoki and Samuli Woolston), also includes a greenhouse module in the structure of an open atrium. This is an example of a minimalist-aesthetic phytomodule that reveals the flora and stylistics of the country, serving cultural-traditional and aesthetic-national aspects. The authors describe it as follows: “On the lower level, the first thing arriving passengers see after passing through customs is the natural diorama ‘Luoto’ – an installation of arbitrary shape with trees, bushes and stones in large pots. ‘Luoto’ combines characteristics of Finnish nature with Japanese garden art. It is also visible from the upper departure level through an opening in the middle of the registration area” (Fig. 1).

The second type of integration – “Greenhouse module – closed atrium” – represents an atrium enclosed by glass around the perimeter, with plants placed in floor-integrated, “sunken” reservoirs with appropriate soil mixtures. Unlike the “open atrium” module, which serves as a unifying element in functional zoning and architectural-compositional solutions of the building, the “closed atrium” module, on the contrary, serves to separate blocks with different functional contents and combines them with architectural-compositional solutions. However, this affects the functional range of using such modules. Buildings with a block volume-planning structure requiring clear functional distribution are suitable for implementation.

In such modules, people mostly stay for a short time, allowing partial simulation of the climate for plants. Since it is a closed-type module, temperature and humidity can be controlled, allowing for a wider range of plants, including those with lower adaptability.

This type is less common, as atriums are usually left open. An example of applying such a volume-planning structure is the Lufthansa Aviation Center, Frankfurt-am-Main, Germany, in 2002-2006. The object is located between the Federal Highway A3 and the Frankfurt Airport. To address issues with the noise threshold and high emissions through such transport hubs, it was decided to alternate office blocks with large greenhouse modules. Each module created typical landscapes of all five continents. Thematic gardens’ vegetation ranges from the “California Beach” to the traditional “Japanese Temple Garden”. Such diversity of landscape themes symbolises Lufthansa’s worldwide connections. An analysis of the vegetation of each region was conducted, and only a few species of trees, shrubs and ground cover plants were selected for each block. This approach helped choose plants with the highest level of inductivity, requiring a more or less similar climate, although they are from completely different climatic zones, resulting in significant cost reduction for creating an identical climate. Each block’s function varies, serving as a different recreation area; for example, one module has a beach volleyball court, while another has a quiet relaxation and meditation zone (Fig. 2).

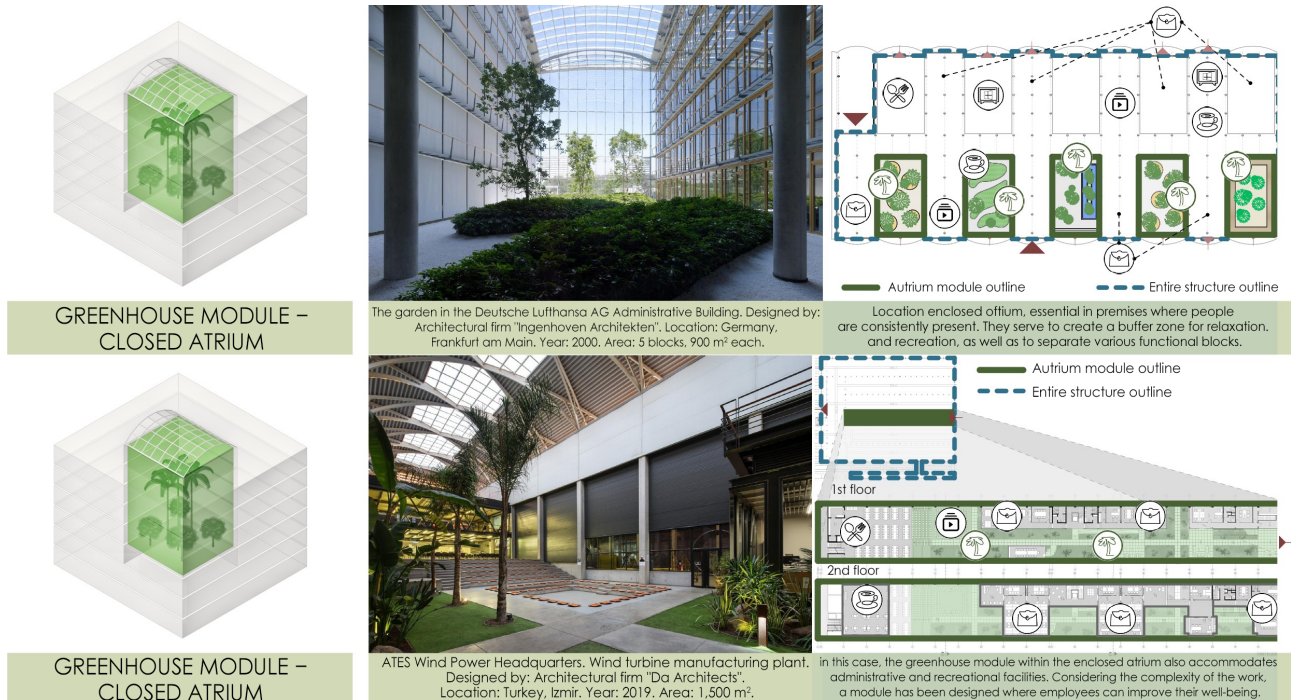


Figure 2. The second type of integration – “Greenhouse module – closed atrium”

Source: developed by the authors based on World Landscape Architecture (2013), ArchDaily (2021a)

The project of the ATES Wind Power headquarters within an industrial facility for wind turbine production, Izmir, Turkey, in 2019, by the architectural firm d.a.architects (chief architect – Durmus Ali Kasap). The object is located along the Gallipoli-Izmir expressway, not far from the Candarli port. The main task facing the architects was to place management offices in the centre of the production workshop with the possibility of direct contact. The solution to this task was the creation of a closed atrium module with an internal garden amidst the production workshops. The module incorporates all necessary zones and rooms (entrance zone, office rooms, small and large conference halls, negotiation rooms, large dining area, amphitheater for meetings and conferences). In their project description, the developers share recommendations they formulated during work: “Effective and efficient organisation of workspaces that meet the company’s actual needs, as well as flexibility to adapt to changing space requirements in the future. Creating diverse covered recreational relaxation areas to enhance social interaction among employees. Using passive design principles such as natural ventilation and lighting” (Fig. 2).

The third type of integration – “Greenhouse module – ‘green’ room” – is a closed glass space with an unlimited number and functional components, and several such integrated modules can be on one floor if needed. These modules are usually small in size and demographically focused on small groups of people; they can be meeting

rooms, conference rooms for a small number of people, rooms for psychological relief, offices for emotional relaxation, meditation rooms, etc. This type of integrated greenhouse is most suitable for buildings where people spend the entire working day, whether it’s office blocks, industrial production blocks, or schools, higher education institutions and others. The “green” room module should be introduced into the structure not just for aesthetic decoration but to improve the ecological-social background of the working environment, so the selection of plants is crucial in such modules to ensure maximum efficient air purification. For practical phytodesign implementation, it was suggested to purposefully introduce medicinal and essential oil tropical and subtropical plants with known healing properties into office interiors, lobbies, waiting rooms, etc. Soon, the creation of phyto-recreations from a professionally selected assortment of plant species for the prevention and treatment of various, including infectious, diseases was highlighted as a separate area – medical phytodesign (Kosenko *et al.*, 2020).

This type is also quite common, for example, in the Shenyang Public Center, China, in 2021, by the architectural firm Urbanus, led by chief architect Hui Wang. This public centre is rich in various green zones, including such an integrated “green” room, which functionally serves as a small meeting room or a room for separate meetings. The room is illuminated by panoramic windows and a skylight, and the vegetation maximally reflects the cultural and traditional features of the local flora and fauna (Fig. 3).



Figure 3. The third type of integration – "Greenhouse module – 'green' room"

Source: developed by the authors based on ArchDaily (2021d; 2022)

In another project of a public centre by Urbanus, led by chief architect Hui Wang, in Shenyang, on the site of old warehouse buildings, a rich variety of green zones has also been implemented. The greenhouse module of the "green" room, in this case, serves as a space for children's games and leisure. The effect of having a garden "will be a real gift for guests from the cold northern region", note the project developers (Fig. 3).

The fourth type of integration – "Greenhouse module – floor" – involves placing an entire greenhouse floor in the structure of a public facility as a buffer between different zones that need to be separated. It is most often located on the first or last floor but can also be implemented in the middle of a high-rise complex (regularly through every few floors). The floor module allows creating more climatic conditions for the quality existence of plants. Moreover, they

have enough space to install air purification and circulation systems throughout the complex. Such experimental mobile greenhouse pavilions were installed in Thailand, developed by the architectural firm Shma Company Limited (2020), where there were significant air pollution problems. The concept of operation of such installations involves obtaining air from the surrounding environment, purifying it from solid particles, achieving the required temperature; passing through the greenhouse module, where saturation with beneficial elements produced by plants occurs and then supplying it to the ventilation system for distribution across all floors (Fig. 4). Such developments for public spaces can complement C. Landry's (2020) creative placemaking strategy, representing a new method of strategic planning that allows transforming the city into a more viable, comfortable and developed place.



Figure 4. Air purification system using a greenhouse module, Thailand, 2021

Source: ArchDaily (2021e)



The project of an integrated “greenhouse module – floor” is arranged on the first floor of the Olivia business centre in Gdansk, Poland, in 2021, designed by the architectural firm Malinowski Design Urban & Landscape. The large business centre (with an area of over 200,000 m²) organised a greenhouse on the first floor, as explained by the architects: “The Nature Connect concept assumes that the properly arranged space can completely reflect the

atmosphere of a natural ecosystem and thereby positively influence people who are there. The garden is decorated with plants from Indonesia, Australia, New Guinea, Madagascar, Venezuela and the tropical forests of the Amazon. For users, we have created four zones: ‘Dialogue,’ ‘Recreation,’ ‘Co-working’ and ‘Food and Drinks’. The implemented climate control system allows creating comfortable conditions for both plants and people” (Fig. 5).



Figure 5. The fourth type of integration – “Greenhouse module – floor”

Source: developed by the authors based on ArchDaily (2020; 2021b)

Gardens within the structure of office establishments that can be used for employee dining are gaining popularity. An example of such coexistence is the project of an administrative building with a rooftop greenhouse in Oberhausen, Germany, 2019, by architect Kuehn Malvezzi. The authors of the project note: “Part of the greenhouse on the roof, which was planned in collaboration with Haas Architekten, is a research area used by the Fraunhofer Institute for Environmental, Safety and Energy Technology in Oberhausen to implement its concepts in the field of integrated agriculture”. The area of such a floor is approximately 1000 m² and includes a lunch and relaxation area and the greenhouse core itself. This project is unique and differs from others considered in that it serves a utilitarian function – growing agricultural crops consumed by employees or for research (Fig. 5). The fifth type of integration – “Greenhouse module – entire

building” – represents a structure with a fully glass envelope, inside of which necessary floors with rooms are located. This is the rarest type of integration, where the impression is created that integration is happening into the structure of the greenhouse facility, not vice versa. Any types of plants can be located in such a greenhouse module, creating the necessary climatic background comfortable for everyone.

Among numerous examples, a unique project is the “Spheres of Amazon” headquarters of Amazon, Seattle, Washington, USA, 2018, by the architectural firm NBBJ. The building consists of three intersecting spheres, reaching a height of about 30 metres and accommodates more than 40,000 plants, samples of which were collected from high-altitude forests on five continents. Inside the spheres, there are four floors of conference rooms, offices, meeting rooms, cafeterias and relaxation areas (Fig. 6).



Figure 6. Types of greenhouse modules integrated into the structure of public buildings

Source: developed by the authors based on ArchDaily (2019)

Another example of a greenhouse module building is an experimental two-story wooden house located inside a greenhouse developed by students from the University of Rotterdam in the Netherlands (Fig. 6). The house consists of two residential floors, each with terraces and areas for planting on the roof of the top floor. The project was created for the study of passive solar heat use in a house surrounded by a greenhouse module to create a comfortable microclimate for both people and plants. A family already lives in the house, which will help students test the energy efficiency and functionality of such an eco-house (Foster, 2016).

Global experience shows that in market economy countries, greenhouse complexes are located in botanical gardens, representing nature conservation institutions, research and educational centres for all layers of the population, from which tourist and recreational complexes, parks of environmental technologies, museums, etc., are created. Since one of the main activities of modern botanical gardens is the protection and restoration of natural territories, botanical gardens are divided into territories that were previously subjected to anthropogenic influence or are unique landscape objects, as confirmed by H. Morchun & O. Martsenyuk (2019).

Long-term stay in artificial environments has provoked the development of ideas for the healthy existence of humans in them. A.M. Grodzinsky considered the main functions of phytodesign to create a pleasant (aesthetically) and comfortable environment that would correspond to the functional purpose of the room. Therewith, the premises would be disinfected from pathogenic bacteria,

viruses, fungi present in the air and on surfaces, purified from foreign gases, dust, volatile emissions of the human body and, conversely, the air would be enriched with substances that affect the well-being of a person working or resting (tonic or soothing effect) (Davydenko, 2013).

Each component of the urbanised urban planning system, whether it be a microdistrict, city, quarter, or individual building, carries a certain anthropogenic load on ecosystems. Therefore, an architectural-ecological approach is necessary for creating environmentally safe, energy-efficient and ecologically comfortable buildings, and structures (Kirnos, 2011). Integrated greenhouse modules implemented in the structures of public buildings are a manifestation of an architectural-ecological approach, specifically aimed at improving the ecological and social background of the working environment. This area of greenhouse structure development is quite popular in modern projects in the United States, European countries and Asia, and has all the prerequisites for successful implementation in buildings and structures in Ukraine (Dunaievskaya, 2023).

The process of integrating a greenhouse module into the structure of a building has also been described by V. Snizhko & I. Kharitonova (2006). They emphasised that for successful integration, rational space planning is necessary not only during construction but also during design. A well-thought-out and properly developed interior space design allows for the most efficient placement of plants to fulfil human life functions. The issue of incorporating "green" modules into the projects of restored industrial objects is relevant for almost every city in Ukraine. Neglected



industrial objects have been preserved in large numbers and their relevance has only increased over the years 2022–2023 due to the war, which has destroyed a significant number of buildings and structures. Some principles and approaches in modern research focus on revealing the recreational potential of the object or adjacent landscape, which should include integrated greenhouse modules and greenhouse structures. The principles of “alternative recreational use of industrial territories” and “optimisation of landscape territory parameters” are of particular importance for coastal cities with significant recreational tourism flows, needs for short-term leisure and “weekend” recreation for the local population, as well as long-term recreation for various groups of vacationers (Storozhuk, 2018). In the list of industrial enterprises that have undergone renovation in Odesa, as of 2021, N. Dmytryk (2021) noted new functions obtained, including student dormitories, trade and entertainment centres, hotels, medical institutions, higher educational institutions and administrative-legal institutions. Greenhouse modules must be integrated into the structure of these objects in the future.

As seen, many issues have been thoroughly and meaningfully discussed, but there is a lack of studies specifically addressing the architectural aspect of greenhouse structures, including integrated greenhouse modules. A greater number of practical developments and theoretical foundations can potentially incorporate such greenhouse modules on a state level into the structure of already built buildings and make them a mandatory parameter in the process of restoring buildings and structures. The functions performed by these modules could also be a crucial aspect for the rehabilitation and restoration of the overall psychosomatic state of the population of Ukraine after the end of military actions in the country.

CONCLUSIONS

As a result of exploring the prospects for the development of modern greenhouses and greenhouse complexes, three major areas can be distinguished. The first area involves the restoration of historical greenhouses while preserving their authentic appearance. In Ukraine, there are many greenhouses requiring immediate reconstruction and restoration. The second is the design of new modern greenhouses. This area will become more relevant when the potential, versatility, and necessity of structures of this typology become clear, using restored historical greenhouses as examples. Factors hindering the development of greenhouse structures include financial constraints, as there are few examples of successful financially active use of greenhouses in Ukrainian practice. The third development area involves the integration of greenhouse modules into the structure of public buildings and facilities, which can be

considered the most promising. Public spaces play a crucial role in city development, and the creation of such “green” modules leads to more favourable working conditions and enhances the comfort level of the population. Greenhouse modules can be arranged in already constructed buildings, especially suitable for the first (open atrium) and third (“green” room) types of greenhouse module integration. During the investigation of the third development area of greenhouse structures, which is considered the most promising for Ukraine, five types of greenhouse module integration into the structure of public buildings and facilities were identified: “module – open atrium”, “module – closed atrium”, “module – ‘green’ room”, “module – floor”, “module – entire building”. Using the graph-analytical method, the functional characteristics of each type were identified and recommendations for suitable structures for placement were provided.

Based on the examined objects, five main recommendations for integrating greenhouse structures into the structure of public facilities were formulated: for greater efficiency of the greenhouse module, it should be designed during the planning stage; when implementing the greenhouse module, the main three aspects – medical, botanical and aesthetic – must be taken into account, with professional input; proper selection of plant assortment will ensure the successful functioning of the module; longevity and decorative appearance of plants can be ensured by following the correct care instructions; creating a greenhouse module in a building should address important issues such as aesthetic appeal, improvement of emotional and psychological well-being, enhancement of indoor air quality and adjustment of temperature and humidity regimes. Considering the previous theoretical findings, the necessary area for further research in this field should involve more specific practical models of integrating greenhouse modules into new designs and models for implementing them into the structure of already built facilities. These models should combine recommendations regarding functional-planning aspects (layout of furniture, pathway systems, pavements and functional content), medical and eco-botanical aspects (plant selection considering climatic features of the project location and the level of necessary improvement of the working environment).

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CONFLICT OF INTEREST

None.

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Інтегрований оранжерейний модуль як один із перспективних напрямків розвитку оранжерейних споруд

Анотація. В статті актуалізується питання оранжерейних споруд України, більшість яких, після активного періоду розбудови (середина – друга половина ХХ ст.), досягла своєї межі в архітектурно-конструктивних та інноваційно-технологічних аспектах, оскільки сучасні науково-практичні праці в галузі архітектури та проектування оранжерейних споруд майже відсутні. Метою даного дослідження є виявлення перспективних напрямків розвитку оранжерейних споруд, встановлення типів інтегрованих оранжерейних модулів та формування основних рекомендацій по їх організації. Методологічний апарат дослідження складається з трьох етапів (підготовчий, дослідницький та синтезуючий) з використанням таких методів: аналіз літературних та наукових джерел, метод термінологічного уточнення понять, метод логічного аналізу, метод критичного та порівняльного аналізу, графоаналітичний метод, узагальнення, метод індукції, метод гіпотези та прогнозування. В результаті дослідження прикладів світового досвіду було виділено п'ять типів інтеграції оранжерейних модулів у структуру будівель та споруд різної типології: «оранжерейний модуль – відкритий атріум», концепція якого полягає у створенні зеленого модулю в просторі відкритого атріуму, для організації культурно-естетичної точки тяжіння; «оранжерейний модуль – закритий атріум», що формується в просторі відокремленого, закритого атріуму, яким розділяють різні функціональні блоки, та створюють буферну зону для працівників заклад; «оранжерейний модуль – «зелені» кімнати», що впроваджуються в ті функціональні блоки, які, в міру своєї специфіки, потребують психологічно-розвантажувальних кабінетів, кімнат емоційної релаксації та медитації; «оранжерейний модуль – поверх», який слугує буферним поверхом між різними функціональними блоками, аби створити для людей комфортний екологічно-соціальний фон робочого середовища; «оранжерейний модуль – вся будівлі» є найбільш рідкісним типом, який підвищує рівень працездатності, мотивації та креативності. Аналіз окремих споруд дозволив виявити наступні рекомендації по інтеграції оранжерейних модулів: оранжерейні модулі треба закладати на етапі проектування; необхідно враховувати медичний, ботанічний та естетичний аспекти; ретельно добирати асортимент рослин; вірний догляд за рослинами забезпечить довголіття модуля; оранжерейний модуль має розв'язувати поставлені задачі. Практичне значення даного дослідження полягає в тому, що результати можна використовувати для створення рекомендацій і методологічних рекомендацій з проектування оранжерейних модулів

Ключові слова: екологічний дизайн; сучасні громадські споруди; фітодекорування інтер'єру; впроваджена оранжерея; фітодизайн; закритий простір

