

# Vertical Farms in the Context of Sustainable Development

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**Abstract:** The article analyzes some of the fundamental aspects of sustainable development of cities, connected in many respects with the concept of ecological architecture. One of the main concepts of sustainability is considered in detail: the city as an eco-sustainable and balanced system, objects of architecture as a full-fledged part of this system, which, most likely, will be determined by one of the directions of this development - the development of landscape architecture as an instrument of integration of nature into the urban environment. At the same time, the variety of its functional forms and architectural methods in the system of organization of internal and external space is outlined, as well as its interrelation with energy-saving architecture, which defines them as the two most important components of eco-sustainable development. Forms of development of landscape architecture are considered in the review of analogs, as an example (an object of agricultural urbanism) a thesis on the topic of "The Vertical Farm Agroindustrial Complex" is presented.

**Keywords:** Sustainability; landscape architecture; ecosystem service; ecoculture, urban farming; vertical farm, aeroponic system

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## 1. Introduction

The Programme corresponds to the trends and requirements of the 2030 Agenda for Sustainable Development, adopted in September 2015 by the leaders of 170 countries at the UN General Assembly in New York<sup>[1, 2]</sup>. The UN Programme includes 17 Global Sustainable Development Goals, which include a universal, flexible and comprehensive plan of action for the world community. The construction of vertical farms contributes to the solution of important five goals from 17<sup>[3]</sup>:

End hunger, achieve food security and improved nutrition and promote sustainable agriculture (SDG 2: Zero hunger);

Ensure access to water and sanitation for all (SDG 6: Clean water and sanitation);

Promote inclusive and sustainable economic growth, employment and decent work for all (SDG 8: Decent work and economic growth);

Make cities inclusive, safe, resilient and sustainable (SDG 11: Sustainable cities and communities);

Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss (SDG

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15: Life on land).

Agricultural urbanism is an approach to urban planning and development, which focuses on the elements of the food system in all city areas<sup>[4]</sup>. The concept of sustainable development of society as a whole implies the implementation of relevant principles in different spheres of existence and human activity taking into account the main criteria of this development. Today, in particular, there are traditionally two major trends in the context of sustainable urban development. The first one is the development and introduction of new technologies in industrial production and the corresponding development of a number of areas in industrial areas. The second trend is the interaction of energy saving and environmental components of landscape architecture. Architecture, being essentially artificially created and, importantly, universal, form of human life, in the future should become "second nature", a space which "is a multidimensional environment and the sub-system of nature in the context of time, information and people; it is non-deterministic and open, as is inherent in any phenomenon of nature"<sup>[5]</sup>. Filling this paradigm with new meaning and given intrinsic and time components of architecture, the interaction of steady and variable, we believe that the main focus in the overall strategy development of sustainability in architecture is sustainability, the development of traditional and current approaches in this area, including innovative technologies in engineering, materials, design and construction.

## 2. International experience

A number of innovative technologies and concepts can be distinguished within the development of sustainable architecture, such as arcology, green architecture, sustainable city, which are often represented by a common definition of 'bioteconic concept' (biomimetics) in the world of design theory and practice. Numerous futuristic projects under the general term 'vegetal architecture' ('a live house', 'a flying eco-garden', 'a vertical park' etc.), of course, carry a grain of truth, based on creating urban quality environment and much needed green areas. An example of such a project is the Flower Tower residential building in Paris, by architect E. Francois<sup>[6]</sup>.

In the "society-man-nature" system of interaction one can distinguish both the anthropogenic impact on the natural environment in all its adverse manifestations, and the environmental influence – that of a natural environment on the process of human life and society. If the urban environment is by nature discrete, nature is a unified interconnected system and urban expansion destroys it. It's safe to say that the first human dwelling was the beginning of the 'assault' on nature. Environmental correlation is viewed as an attempt to make up for the damage that urbanization inflicts on nature, through the creation of artificial natural environment of the urban ecosystem. These are the elements of urban landscape: green recreation areas, streets and yards; environmental and recreational facilities; internal landscaping in buildings and, of course (popular today) vertical facade greening and roof greening (which to some extent compensates for the potential opportunity for landscaping of the site and contributes to urban green areas). Competent approach to the creation of such green spaces by optimizing natural systems at the scale of building in general not only has no negative impact on the environment, but complements it, creating attractive and interactive public spaces and, thus, reflects one of the basic principles of the sustainable development strategy. Energy-efficient architecture involves a mutually beneficial exchange of resources with the environment on the basis of parity and mutual respect with the use of renewable energy sources in integrated (engineering) systems built into the building, as well as traditional layout techniques: passive architectural design solutions and adaptable forms of buildings. Landscape architecture currently is not just the use of historically traditional forms of landscape art, new techniques, new ideas and ways of natural "penetration" into the fabric of the city and the interior space of buildings. The significance and relationship of these positions in the framework of the concept of "sustainability" are obvious.

Landscape architecture today is actively conquering the urban space. It includes open recreational areas - loggias, balconies, terraces, roofs; internal public atrium spaces, "relief-buildings", urban eco-gardens and farms. The concept of biological eco-gardens is developed in the creation of urban farms for growing vegetables, fruits, medicinal herbs within the boundaries of urban development, on vacant and brownfield sites with a view to their rehabilitation, as well as through the integration of garden spaces in neighborhoods to provide residents with fresh food.

It is no secret that traditional agriculture leads to a number of problems: first, it is the desertification of land; secondly, the inhabitants of big cities have to put up with the impressive costs that arise while delivering food from its place of production to the consumer; thirdly, in agriculture, many production processes are of a seasonal nature, as connected with the natural conditions of plant growth, development, animals and depend on climatic conditions, which is especially relevant given climate change on a planetary scale; no less important is the fact that the emergence of insect pests and weeds in aeroponics is out of the question.

Scientists predict that by 2025, more than 70 %, and by 2050, 80 % of the world's population will live in urban settlements and the population of the Earth in January 2016 crossed the threshold of 7.3 billion people and in around 40 years will increase to 9 billion, which makes the problem of rational use of the planet's resources and in this regard the production of quality food products particularly relevant. Parallel to the process of urbanization is the outflow of the rural population; according to statistics, urban population has been steadily increasing; over the past 100 years the process of urbanization in Russia has led to the fact that the proportion of the population in urban areas has increased from 17.5 % in 1914, to 74.2 % in 2014.

The urban farm is the development direction of the urban landscape, which is associated with the introduction of new industrial technologies of agricultural production and ecosystem service. There are plenty of projects, including those already implemented today. The formation of urban farming in the "edible landscape" and eco complexes is successfully implemented in several cities. Known commercial farms in residential complexes, mini-farms in low-rise residential groups, farm stores, farm schools, farm-restaurants, farms, scientific centers, etc.

The design of residential-agrarian complex at the University of Waterloo (Britain, architect G. Earl) is a model combining dwelling and public farms, the functioning of which is technologically interconnected, including alternative energy sources, and residents of the whole complex will be provided with fresh food all year round. A cooperative residential building in Toronto (Canada, architectural group "Teple Architects") with a built-in restaurant and culinary training center is attractive not only with its remarkable architecture, but also ingenious technological "add-on": vegetables and herbs for the restaurant are grown on the terraces<sup>[7]</sup>.

Thus, the design of the area of Eco-Viikki in Helsinki takes into account not only the factors of energy efficiency, but also environmental and social aspects that, in general, determine the quality of the environment at home, at the workplace, in public spaces<sup>[8]</sup>. Residential houses and infrastructure with new and unique for traditional neighborhood objects: the Centre of Biotechnology of the University of Helsinki with a Science Park, the Center of Horticulture for the residents.

Architectural firm SPARC (Singapore) presented a draft of an assisted living facility (**Figure 3**), in which the vertical farm system of cultivation of horticulture products is installed; there is a rooftop garden which allows residents to participate in the overall process, to stay active and receive fresh, organic food. The plot includes a mini-market for the sale of the farm products, and biomass power plants. The building has a quaint, but sophisticated shape with a courtyard, the walls of which are arranged in terraces with vertical gardens on the basis of aquaponics, the active use of rainwater, waste from fish farming as fertilizer. According to statistics, in Singapore by 2030 one-fifth of the population will be represented by residents over 65 years of age, which requires special attention to the issue, and such approach is especially welcome. According to the forecasts of developers, the first house may appear in the Malaysian capital Kuala Lumpur in 2018<sup>[9]</sup>.

The idea of introducing the urban farm project into a complex of school facilities (school farm) is implemented in an innovative project of the architectural Bureau "Natoma Architects" for the Golden Bridges city school in San Francisco <sup>[10]</sup>. The goal is to educate the younger generation on the environmental program of Waldorf pedagogy, the essence of which is the development of not only intellectual and social abilities, but also moral qualities and practical skills for understanding wildlife and connection with the land. The concept of the project is a building inscribed into the landscape, and is intended to become the applied part of education, according to the authors: "This building is a teaching tool, and the landscape is a learning tool"<sup>[11,12]</sup>.

### 3. Architectural solutions

At the Department of Architecture in the Institute of Civil Engineering, URFU in 2015, an 'Agriculture-Vertical Farm' project for the Ural region was developed (**Figure 1**). The concept was formed based on all these factors and in the context of modern sustainability criteria. The main goal of this work is the development of the direction of "agricultural urbanism" as an example of the interaction between production, science, education and business, taking into account the main criteria of sustainability in architecture.

The area where the urban farm is planned to be built is located two kilometers from Studenchesky village of district Beloyarsky and fifty kilometers from Yekaterinburg. It is easily accessible: there are major highways and railway lines, which is particularly important for this project technology.

The designed facility is a multifunctional building – a laboratory for scientific research and development, including the area for the practical implementation of innovative high-tech methods like hydroponics and aeroponics[13], which are the fundamental basis for the installation of vertical farms and where different kinds of vegetables, greens, berries, medicinal plants and other crops can be cultivated in an artificial environment. In a number of fundamental design decisions of the facilities of vertical urban farming a combination of aeroponics systems and soil agriculture at a particular processing scheme is used. The building has an academic block for students of the Agricultural Academy.



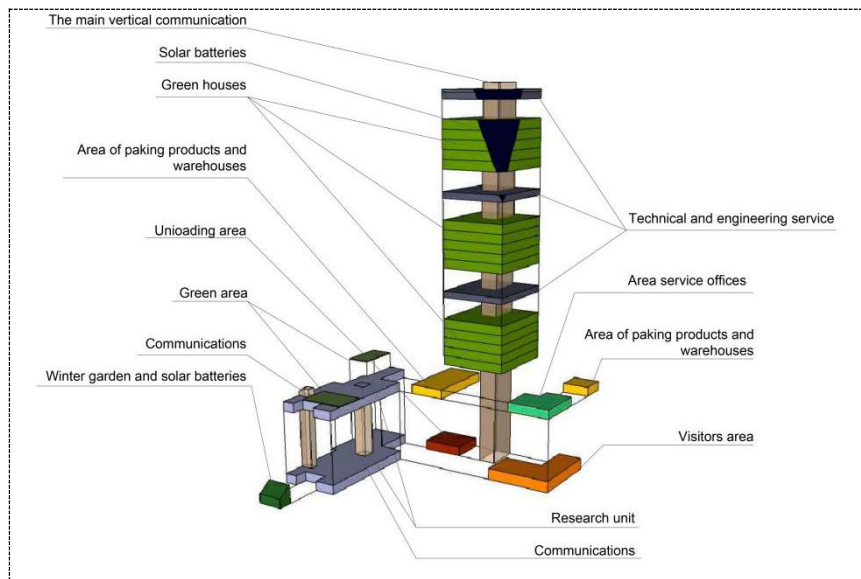
**Figure 1.** The agro-industrial complex "Vertical Farm"

Although the underlying principle of innovative methods is quite simple: plants need light, air, water, heat, nutrients, and soil is unnecessary; the roots can get the mineral nutrients required for plant growth from the nutrient solution. This method is not new, but requires a serious approach to its promotion and practical implementation in Russia. It should be noted that the idea of urban farming has also a social aspect as a new principle of educating people to interact with the built environment and education of ecological culture<sup>[14]</sup>.

The building of this agricultural complex combines two main functional structures. Practically oriented research unit with laboratories, classrooms, auditoriums, rest areas and catering located in a 2-storey volume. Manufacturing unit, consisting of several modules for the cultivation of products and support services, is housed in the high-rise section.

The ground floor of the production block houses a shopping and exhibition area for visitors, the area of preparation and transportation of the products grown in module greenhouses. On the second floor there are service and office areas, as well as storage and packing areas for grown foods. Research and production units are linked at the level of the 2nd floor, while maintaining technological independence and a comfortable functional relationship. Mini technological complexes are located above, floor by floor: greenhouses, service offices, a mini laboratory and technological facilities.

Flexibility of internal space allows you to select the optimal planning distribution of components within each floor, taking into account the specifics of growing agricultural crops, which reflects the principles of multifunctionality and sustainability.



**Figure 2.** Scheme of the functional structure of agriculture-vertical farm

The space-planning structure of the high-rise section of the building consists of three modules, divided by technical floors (Fig. 2). The developed module space-planning scheme provides options for introduction into various structures of the public service. Similar structures can be built as a city-wide market complexes and large shopping complexes, small shopping farms within the system of a residential area or in locked and low-rise cottage villages, and with the possibility of jobs for the residents. One can consider the construction of such buildings in industrial areas, particularly in remote ones, and also for internal use in the catering system.

## 4. Energy saving

The design choices meet the requirements of green building at all stages of the life cycle of the building. In order to increase energy efficiency alternative energy sources are used, such as solar panels (PANASONIC HIT-H250-E01) in the glazing of the winter garden and on the facade of a tall part of the building<sup>[15,16]</sup>. A system of vacuum solar collectors (Viessmann Vitosol 300-T) was designed on the roof to partially satisfy the need for hot water. A system of collectors is connected to a common accumulating reservoir via the optional expansion tank located on the technical floor. The latter is required for regulation of pressure differences and improvement of maintainability and reliability of the water supply system. On the technical floor there is also a heat pump for waste water, which makes it possible to intercept the drains of the bathrooms before they leave the building, and their temperature falls below 21°C, and to use them later for heating and technical needs. In addition, for air preheating in winter and cooling in summer a soil heat exchanger is provided, as well as vertical U-shaped ground heat collectors.

In such high-tech buildings it is appropriate to support intelligent power distribution according to the concept of Smart Grid: part of the energy obtained from renewable sources is stored in storage tanks for the building's internal use, but often with favorable climatic conditions or the fall in energy consumption excess can occur, which will be used for local station electrolysis. Thus, electricity is stored as hydrogen, which can be used as fuel for car vehicles, industrial raw materials or compensatory source of energy. The feedback system helps to dynamically regulate the ratio of traditional and alternative energy sources in the overall balance.

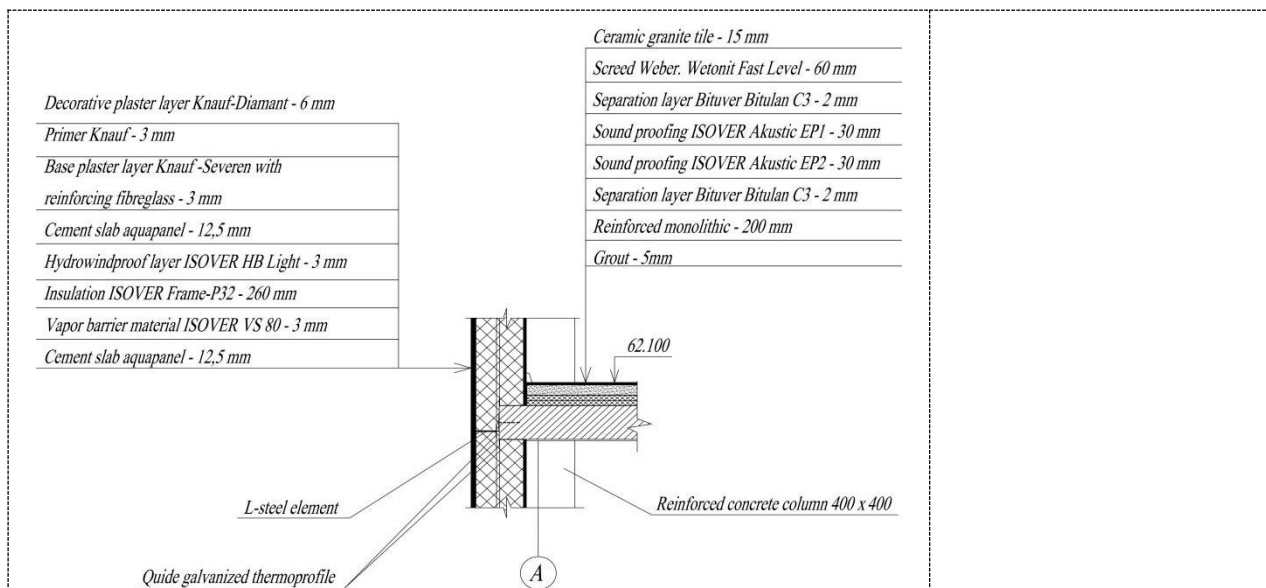
Forced ventilation with heat recovery is installed in the building. Heating is carried out by preheating the supply air. Recovery system and other equipment are located on the technical floor.

A frame without beams was chosen as a structural system, which provides the interior space and the reliability of nodal solutions: monolithic concrete columns 400x400 mm, on which lies a hard monolithic floor slab, 200 mm thick. The central staircase and elevator section in the high-rise part of the building is a monolithic hardness kernel. The foundation is made in the form of monolithic reinforced concrete slab, to prevent uneven sediment and reduction of transmission heat loss in underground space.

Thermal insulation of building structures is of great importance from the point of view of efficiency and environmental of the future project, as it saves more energy in its lifetime than is spent on its production and disposal. Therefore, the properties and quality of insulation deserve careful attention as one of the criteria of green building.

## 5. Structural solutions

The constructive solution of the exterior walls involves aquapanel facade frames made of thermo-profiles<sup>[17]</sup>. The best option for the elimination of "cold bridges" (overseas "thermal bridges") is the construction of exterior walls with two wall panels, one in the ceiling and one for the outline of the building on the mounting brackets (Figure 3).



**Figure 3.** The Assembly monolithic slab and facade systems using aquapanel

Steel thermo-profiles<sup>[18,19]</sup> for exterior walls with staggered perforations have high thermal and acoustic properties, which increases the efficiency and operating characteristics of the design. Overall, this facade system, due to its light weight and high resistance to heat transfer, contributes to reduction of primary energy consumption to 50 %; reduction of logistics costs; reduction of CO<sup>2</sup> emissions to 30 %; reduction of the use of natural resources, including water, due to the method of dry construction, which makes a significant contribution to ecosustainability of construction. In addition, the dismantling and recycling at the end of the operational cycle is very simple, and the waste can be easily sorted by content, which reduces the volume of waste and increases the degree of its recovery.

Window structures and glazing in the system of thermal shell of the building should meet high standards for resistance to heat, natural lighting for regulation of direct sunlight, to create comfortable conditions for people and plants. The translucent systems of "Electrochrome Sageglass Saint-Gobain" meets these requirements<sup>[20]</sup>. They represent an 'active' structure. Firstly, they are a part of the heating system of the building, preventing the formation of thrust and condensate. Secondly, they change from transparent to very dark, depending on weather conditions.

This prevents overheating in office buildings in hot sunny weather, making it possible to regulate the penetration of direct light on plants, which prevents leaf burns.

Soundproofing and vibration reduction in communication spaces is achieved by using embedded elements and "Schöck Tronsole" damping pads. The required sound insulation performance in various premises in the

multifunctional building is achieved by using high-tech reliable "aguapanel" as partitions, consisting of "Knauf" cement plates on a single steel frame and sound insulating layer of "ISOVER acoustic boards EP12". The system of floating floor provides sound insulation through the separation layer, which is applied to "ISOVER acoustic boards EP1" and "EP2 ISOVER acoustic boards" plates<sup>[21,22]</sup>. All structural joints are made with application of damping pads and sealant for elimination of acoustic bridges.

## 6. Conclusion

Agricultural urbanism should be an important component in the creation and development of urban environment, urban planning and solving the food problem. The development of such systems, in particular urban farms, and aeroponic systems, their integration into urban space as separate architectural objects is the next step after the task of saving and using their achievement, towards the development of new technologies and a more socially and culturally sustainable food program. Landscape architecture is also an important component of sustainability and of ecological culture, in particular, of a new level of balanced relationships between man and nature, a new outlook, the most important factor in achieving social stability and harmony.

## References

1. There is consensus on a new program for sustainable development in. In UN Information Center in Moscow 2015 <http://www.unic.ru/bulletin/2015-8-05/dostignut-konsensus-po-novoi-programme-ustoichivogo-razvitiya-kotoraya-dolzha-by>.
2. Transformation of our world: Agenda for sustainable development for the period up to 2030. United Nations. - A / RES / 70/1 General Assembly Distr: General 21 October 2015 pp 2– 44.
3. Kim JB, Jeong WS, Clayton MJ, Haberl JS, Yan W. Developing a physical BIM library for building thermal energy simulation. *Automation in Construction* 2015, 50: 16-28.
4. Food city: The urban landscape as a food source 2016 *Green Buildings* 3 p 30.
5. Shayk AK. 2012 System perception of sustainable architecture in the beginning of the XXI century. "Sustainable architecture: present and future": Proceedings of the International Symposium on 17-18 November 2011, scientific papers of the Moscow Architectural Institute (State Academy) and group KNAUF CIS pp 80–85.
6. François E. Flower Tower 2004 <http://archi.ru/projects/world/4937/dom-flower-tower>.
7. Bulgac RV. 2012 Sustainable urban development and environmental architecture. "Sustainable architecture: present and future": Proceedings of the International Symposium on 17-18 November 2011, scientific papers of the Moscow Architectural Institute (State Academy) and group KNAUF CIS pp 236–249.
8. The greenhouse area of Eco-Viikki. PIMWAG, Helsinki // <http://www.archplaforma.ru/?act=1&nwid=2984> - date of the application 10.03.2017.
9. The urban farm: The fresh products from the skies 2015 *Green Buildings* 4 p 31.
10. Home farm, Architecture with greenery 2015 [http://mirum.ru/news/world\\_trend/obraz\\_zhizni/v\\_singapore\\_pridumali\\_pansionat\\_fermu\\_dlya\\_pozhilykh/](http://mirum.ru/news/world_trend/obraz_zhizni/v_singapore_pridumali_pansionat_fermu_dlya_pozhilykh/) - date of the application 12.03.2017.
11. A school where building bridges 2016 *Green Buildings* 3 p 47.
12. Nature in the living body, a city 2016 *Green Buildings* 2 p 30.
13. Roksolana. 2016 What is hydroponics and aeroponics? Innovative technologies of plants cultivation In Russian [Что такое гидропоника и аэропоника? Инновационные технологии выращивания растений] <https://na-poluostrove.ru/blog/chto-takoe-gidroponika-i-aeroponika-innovacionnye-tehnologii-vyrashchivaniya-rasteniy> - date of the application 10.03.2017.
14. Golovnev SG. 2010 Modern construction techniques In Russian [Современные строительные технологии] (Chelyabinsk: Publishing center SUSU) С 38.
15. Solar battery Panasonic HIT VBHN330SJ47 <http://alteco.in.ua/products/solnechnue-batarei/solnechnue-batarei/panasonic-hit-vbhn-330-sj47-detail> - date of the application 10.03.2017.
16. Panasonic introduced the most efficient solar battery. 2013 <http://sun-shines.ru/panasonic-rekord/> - date of the application 14.03.2017.
17. Aquapanel "Knauf": Specifications, main parameters, benefits. 2015 In Russian [Аквапанель "Кнауф": технические характеристики, основные параметры, преимущества] <http://fb.ru/article/198210/akvapanel-knauf-tehnicheskie-harakteristiki-osnovnyie-parametryi-preimuschestva> - date of the application 17.03.2017.
18. STO 42481025 006-2007 Specifications. Bent steel thermoprofiles for building structures 2007 In Russian [СТО 42481025 006-2007 Технические условия. Термопрофили стальные гнутые для строительных конструкций]

(Closed joint-stock company "INSI")

19. Thermoprofile: features and material characteristics: Information and building foundation of my house In Russian [Термопрофиль: особенности и характеристики материала: Информационно-строительная основа моего дома] <http://osnovam.ru/stroitelnye/termoprofil>.
20. Solutions for Facades 2014 [http://www.foams.saint-gobain.eu/uploadedFiles/SGfoamseu/Documents/StructuralGlazing\\_Fa%C3%A7ades\\_en.pdf](http://www.foams.saint-gobain.eu/uploadedFiles/SGfoamseu/Documents/StructuralGlazing_Fa%C3%A7ades_en.pdf).
21. Insulation Isover: Technical characteristics and properties 2016 In Russian [Утеплитель ИзOVER: технические характеристики и свойства] <http://srbu.ru/stroitelnye-materialy/79-uteplitel-izover-tehnicheskie-kharakteristiki-i-svoystva.html>.
22. Insulation Isover – features: Sound insulation and thermal insulation In Russian [Утеплитель ИзOVER – характеристики: шумоизоляция и теплоизоляция] <http://okrovle.com/teplo-paro-gidroizolyatsiya-krysh/teploizolyatsiya-krysh/uteplitel-izover-kharakteristiki.html>.
23. Mineral wool Isover: Specifications In Russian [Минвата ИзOVER: технические характеристики] <http://srbu.ru/stroitelnye-materialy/79-uteplitel-izover-tehnicheskie-kharakteristiki-i-svoystva.html>.