Chapter 7

Modular Green Roofs in Urban Ecospace

Elena Korol and Natalia Shushunova

Additional information is available at the end of the chapter

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Abstract

This chapter essentially starts with green roof systems in an overview of the green building industry. Various green roof systems, traditional green roof structures, and innovative modular green roofs are also examined. The advantages of these systems are delineated. Likewise, the most important green roof technologies, the factors that impact the decision to choose roofing system, which are recommended for adoption, are discussed. The greatest value of installing modular green roof systems as a successful solution for urban ecospaces is also explained here. Green roof benefits and values are considered as well as important advance on sustainable development of landscape planning and design of the environment, including modern green infrastructure elements. This study analyses both traditional green roof structures, co-called green roof "pie," and innovative modular green roof systems. Finally, the influence and impact of green features on green building development and standard documents required and related issues are examined.

Keywords: modular green roof system, urban ecospace, innovative green roof technology, green roof "pie", livable ecosystems, green building development

1. Introduction

In high-density urban areas, quickly installed modular green roof system gains success and has a high potential in solving problems such as the lack of urban space, green areas. Modern park-like design of green roof creates great well-being areas in urban ecospace. These innovative systems consist of the green roofs with the integration of supported integrated solar and wind energy collecting and converting devices and including an irrigation system. Many studies provide evidence for the benefits of the modular green roof system in urban green space with microclimate differences. The big cities hold several environmental challenges: they

occupy 3% of the land surface, host 50% of global population, consume 75% of natural resources, produce 50% of the global waste and emit 60–80% of greenhouse gases (GHG) [1].

Modern green roof technologies are seen as a key strategy to improve urban development, the environmental quality, sustainability and livability of cities. Smart progressive technologies in green buildings such as green roof and green wall systems have multiplicity aspects of a modern eco-style house, forming a living, breathing ecosystem for healthy urbanites. The modular green roof is increasingly dynamic part of the ever-growing green building sector. These coatings form a modular living system on the roofs of large commercial and office buildings and residential buildings. This paper reminds us that research regarding roofing ecosystem provided by the urban landscaping needs to be translated into robust and practical tools for changes in urban planning and management. The modular green roof system is a technically advanced design solution erection of roofing, as well as innovative technological solutions with a number of functional advantages and the ability to integrate devices that convert solar and wind energy-solar panels, LED-lamps, micro wind turbines as known as wind generators.

The sloped modular green roof system is used adjustable supports to the desired height and construction of communications, network hose for watering, that provides quick and easy access to staff to monitor the status of the waterproofing layer. The stormwater retention is also particularly important in big cities where it is difficult to manage the water free flowing off impervious roof surfaces during a storm. The adjustable leveling structures allow the bottom of the modular tray to be adjusted with respect to underlying roofing structures. It should be noted that other surfaces could be covered, including horizontal surfaces that form part of building structures: terraces, patios, decks, and ledges.

2. Key benefits of green roof systems

Green roof system with modular trays is better than the conventional green roofs. The advantages of pre-planting modular trays before traditional green roof structures with green roof "pie" are more easier to place on the roof structure, improved esthetics, incentive using in maintenance as well as security procuring. The modular green roof system is a technically advanced design solution of roofing, as well as innovative technological solutions with a number of functional advantages and the ability to integrate devices that convert solar and wind energy-solar panels and micro wind turbines. Modular trays are equipped with drip irrigation systems to create a microclimate zone directly above the roof of green building. The research describes modern green roof system that consists of the green roof modular pots with a big variety of configurations and integrated devices (**Figure 1**).

Widely, there are great positions on the benefits and improvements of green roof system in urban space. Key benefits of green roof systems are following:

- Green roof installation provides energy savings. In London, a building services manager revealed that the application of a retrofitted green roof on a building had reduced the

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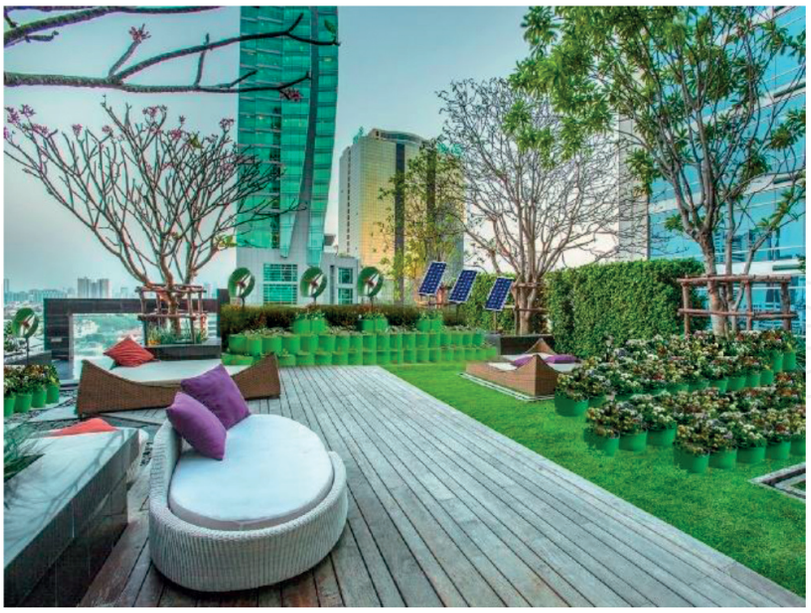

Figure 1. Modular green roofs in urban ecospace.

need for cooling/heating in the floor beneath. If the green roof had been installed as part of the original design of the building and the ability of the green roof to reduce cooling and heating requirements had been known, there would have been a big potential of energy efficiency of buildings. The energy savings both in heating and cooling are maximized underneath the green roof. The positive impact of green roof system on the energy performance of the buildings becomes more evident and noticeable.

- Mitigation of the urban heat island (UHI). The vegetative layer of the green roof reduces the harmful substances in the air due to the absorption of carbon dioxide CO_2 and the release of oxygen. The green roof system neutralizes a significant amount of dust and harmful gases. According to researching of [2] spirit on the green roof is much cleaner and contains 37% less sulfur dioxide (SO_2) and 21% less carbon monoxide (CO). The green roof additionally moistens the air, increase the longevity of the roof structure several times (3–4 times).
- Reduction of noise level up to 8–10 db. The soil is capable of absorbing the lower frequencies, and the vegetation is high, also the layer of soil cover is fireproofing, in case of fire, the soil layer will prevent its spread. Acoustic is cataloged as one of the major factors in the built environment quality.
- Versatile installation schemes and types of the green roof system, an improved method for roof covering. Protection of the roof membrane against extreme temperature fluctuations, UV radiation and physical damage from maintenance period, greened roof can double the material life.
- Lightweight, modularity, and modern park-like design of green roof system with reversible interlocking means that easy and quick to install, dismounting and maintenance.

- Effective water flow runoff management of green roof systems, that provide water supply be special hydroponics system, including automatic watering system, pipes, and ducts for water transfer (**Figure 2**). The Australian water sensitive urban design (WSUD) is now increasingly used internationally, and strong collaboration is between champions in the United Kingdom and New Zealand [3].

- Plant diversity and multiplicity of modules comprise different configurations, sizes of diameters and heights that allow to use both intensive and extensive roof greening structures. The plants are selected according to the specific geographic zone and climate characteristics and green roof type such as extensive, semi-intensive and intensive roofs. And it shows interest in installation of this biggest variant of green roofs and their geographic applicability, which is available in many regions. It is important in selecting, that plants have fluence on the roof's performance and its tolerance to drought, wind, light, shade and pollutants. According to some studies, the extensive and semi-intensive green roof types are currently used a narrow spectrum of plant species due to their relatively harsh growing environment which includes shallow rooting depth, high wind stress, and fluctuating substrate temperatures. The low-growing plants may include a wider range of plant species such as *Arenaria montana*, *Arenaria balearica*, *Arenaria sagina subulata* "Aurea," collectively referred to as "Shortgrass Meadow Plantings." As another example, the vegetation could include another mixture of vegetation such as *Sedum acre* "Aureum," *Sedum album* "Coral Carpet," Sedum spatulifolium "Purpureum," *Sedum spathulifolium* "Cape Blanco," *Sedum spurium* "Green Mantle," *Sedum spurium* "Red Carpet," and *Sedum kamtschaticum* "Variegatum" (collectively referred to as "Desert Succulent

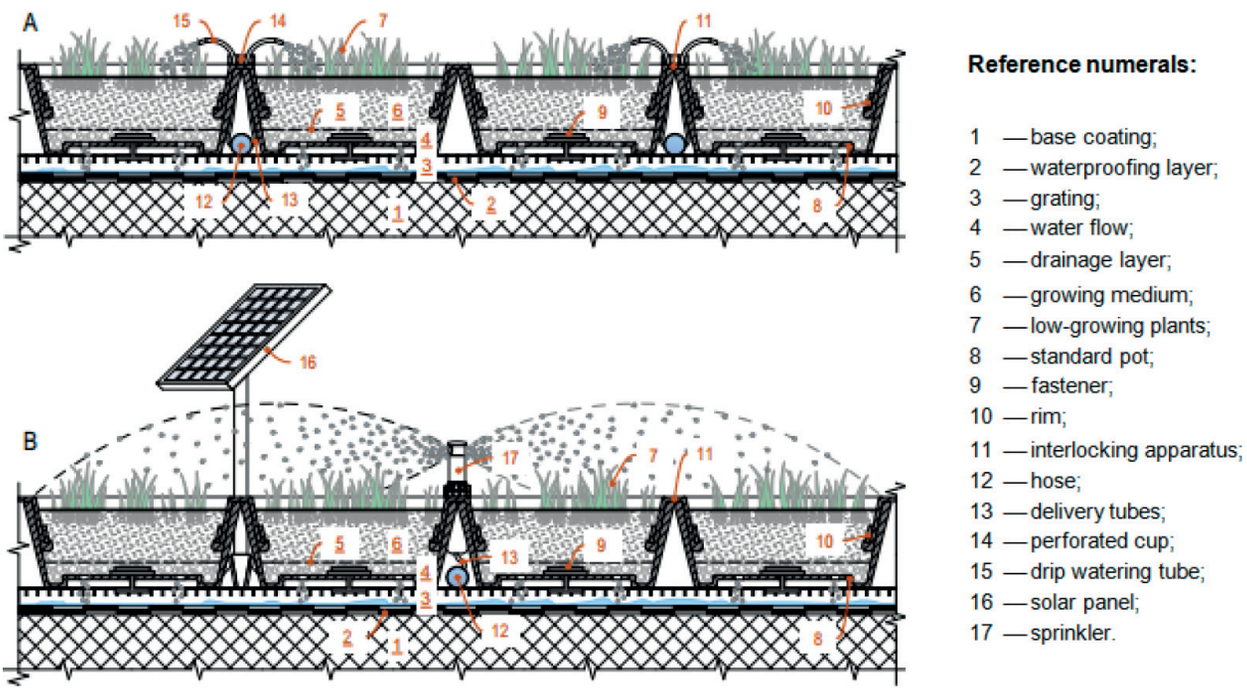

Figure 2. Integrated solar panels and hydroponics of green roof system.

Plantings"), *Sedum spurium* "Summer Glory," collectively referred to as "Desert Succulent Plantings," "Albertiana Conica," *Picea pungens* "Globosa," *Picea pungens* "Glauca Prostrata," and others. Additionally, there can be joined other grasses, herbs, and mosses.

Typically plant cultivation manner is to supply nutrients through "soil". Alternatively, plants modules could be supplied without vegetation, for example, with only the growing medium or non-soil growing medium. This technique is so called "hydroponics" method. Hydroponics is a subset of hydroculture, using mineral nutrient solutions, in water, without soil, so thus giving the plants the maximum amounts of both nutrients and air to the plant root. According to it, fillings of plants modules presented plenty of solid growing medium, such as gravel, expanded clay, shingle, growstones, pumice, rock wool, perlite, vermiculite, coconut fiber, rice husks, thatch, straw, sand, or the like. In study [4] the impact of two substrate components assessed: brick particle size and a polyacrylamide gel additive, living mulch on the growth, physiological and visual health of newly established green rooftops during 25 days of extreme drought, and this study shows that coarser particle size substrates can significantly improve the drought tolerance of plants on green roof.

The alternative embodiment of the modular green roof system, illustrating modular pots of different configurations with various fillings and using the adjustable leveling device on a sloped roof is shown in **Figure 3**. The waterproofing layer is placed on the rooftop deck. Then adjustable leveling devices are installed on the waterproofing layer and fixing the standard pots to the grating assembled on the adjustable leveling devices by elongated fasteners. Further, it takes place the installation process of the standard pot with successively filling of drainage layer, growing medium and low-growing plants and alternatively fixing to the grating is by inserting fastener using centrally mortise. The interlocking apparatus penetrate into the modular pot with a rim until it clicks. In this case, roofs having slopes is 1,5 to 3%, which allows water flow, resulting by the irrigation water or rainwater to percolates vertically through the growing medium of the standard pots and further to drain away freely on a

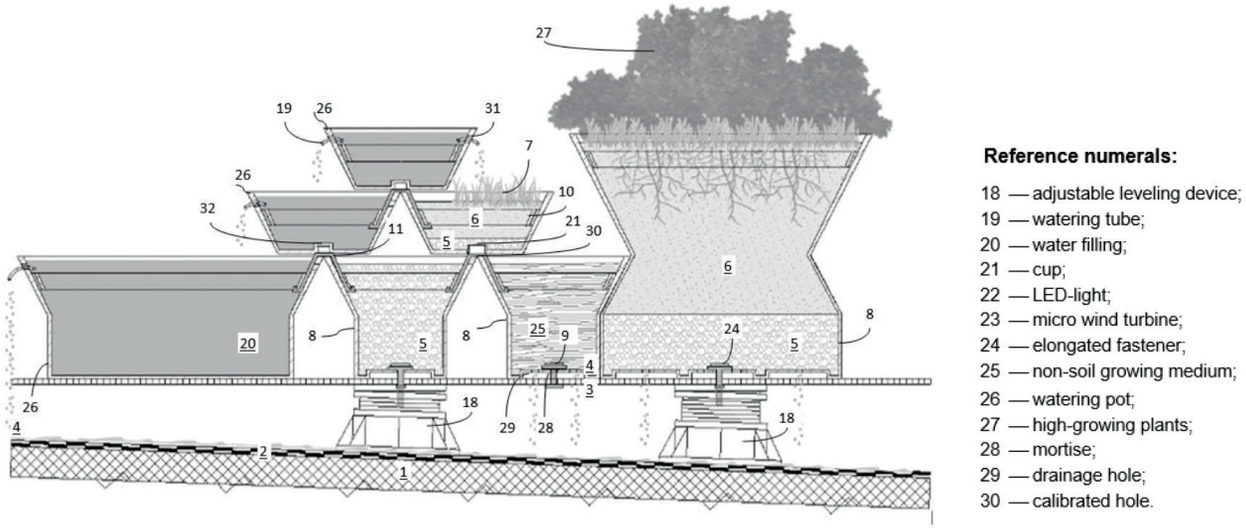

Figure 3. Cross-sectional view of the green roof system with adjustable leveling.

surface of a sloped roof. The water flow passes through drainage holes that in the bottom of the standard pot. The water flow from watering tubes, which passing through diametrically opposed outlets in the side surface of the pot, supply both the standard pot and watering pot with water filling. Additionally, the modular pots can be installed on each other forming the multi-level system using the calibrated hole inside the standard pot on interlocking apparatus, which covered by the special cup. In the same manner protuberance inside the watering pot is adapted to install it on each other on interlocking apparatus.

Typically plant cultivation manner is to supply nutrients through the soil. Alternatively, standard pot could be supplied without vegetation, for example, with only the growing medium or non-soil growing medium. This technique is so-called "hydroponics" method. Hydroponics is a subset of hydroculture, using mineral nutrient solutions, in water, without soil, so thus giving the plants the maximum amounts of both nutrients and air to the plant root. According to it, fillings of standard pots presented plenty of solid growing media, such as gravel, expanded clay, shingle, growstones, pumice, rock wool, perlite, vermiculite, coconut fiber, rice husks, thatch, straw, sand, or the like. The wide choice of the growing medium and moreover using the "hydroponics" method provide advantages over the prior art in that it consequently significantly reduces the pressure on the environment in view of the fact soil is not renewable.

The original modular design is another advantage of the modular green roof system. This allows you to cover the surface of any configuration with various forming parts, for example, ledges rounded and cropped corners on rooftops, edges of pools, fountains and many others. The interlocking apparatus is provided with a lighting system that in form of, for example, solar lamps and LED-lights. This can illuminate the environment as daylight and it is likewise spectacularly viewed at the night time. Modular green roof system provides esthetic benefits and serves as a major amenity for building occupants as these "landscaping and living roof" gain in prevalence and popularity. So, using alfresco aquarium is integrated in modular green roof system element of urban space together round-curving lines of balcony edges added more esthetic value to roof view. It can easily fit into the design with arched vaults and similar objects.

Modular green roof systems are provided favorable well-being conditions for living in the new and recreated rooftop projects of residential, public and commercial buildings, trade and office centers. Furthermore, these systems could be used partially in the country houses space as landscaping system to promote healthy conditions. With the combination of build-up energy-effective devices, such as "Smartflower," which is also completely automatic, there is formed interflow impersonation of the modular green roof system. It directs its solar modular fan on a surface area of 18 m^2 towards the sun and begins producing electricity by device dual-axle sun tracking, the fan moves reliably along with the sun throughout the day. Thus, 1 year of use the "Smartflower" system equals 4.000 kWh—the average complete annual consumption of a central European household [5].

In comparison with the static rooftop systems, the unit starts earlier in order to produce the exact amount of needed electricity. It consistently maintains the electricity supply and even uses the energy from the last sun rays efficiently enough to cover early evening electricity requirements (**Figure 4**).

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Figure 4. Energy-effective devices build-up in modular green roof system.

The present roofing system is to be solved various problems of roof covering by making inexpensive, little expenditure of labor and waste-free assembling based on the principle of building kit. This future-oriented green technology is developed of the urban spaces of tomorrow from the viewpoint of a wide range of sustainability aspects and supports the development of integral solutions from a systems perspective. The unique configuration of the system with an unusual combination of architectural and esthetic design solutions gives a beautiful appearance to the urban areas and also allows to use methods of landscaping on living roof. The green roof technology includes the apparatus to integrate a plurality of special roof covering elements with aspects of energy collecting and converting devices.

The essence of this innovation solution is the fact that covering surface on the building roof is covered with special modular trays with vegetation that fixed to the gratings by engagements. Modular trays are equipped with irrigation and drip irrigation systems to create a microclimate zone directly above the roof of the building. While the green roof covering modular device must be observed and control the green roof installation process.

For the study of green building in the evaluation of building energy performance and thermal comfort, the methods of modeling by the WUFI®-Software are used (**Figure 5**). The object of the study is a flat green roof covering of 100 m^2 with a slope of 1.5−3.0%, located at a height of up to 15 m with a base of reinforced concrete slabs.

2.1. Green roof installation quality according to the green standards and green roof code

The installation process has the following steps:

- The correct and consistent installation process of the waterproofing layer and its compliance with the project specification. Proper installation of irrigation systems and drip irrigation, and matching their capacities and an operating mode with the required parameters in accordance with the provisions of the Green roof standards, called also Green roof Code, that consist of special requirements for the device, and the rules of acceptance of control.
- Quality control of the roofing and grating mounting processes. According to the map of quality control processes have to be controlled. It should also be noted that the performance

of work report of the roofing system installation must be carried out in the general journal papers or special journals of the installation process on the forms that considered in Russian requirements. To date, the most widely accepted standard among the leading green roof suppliers is the German FLL standards, the landscaping, and landscape Development Research Society. This standard is generally recognized as the benchmark for green roof installation quality. According to the German FLL standard, a successful green roof system must basically replicate nature and consist of the protection layer, drainage and filter layers, growing medium, appropriate components for vegetation and irrigation.

Big cities are adopting new building codes that incentivize adoption of innovative technologies in modern buildings. The green construction industry is moving fast, together with a growing trend for Green Building Rating Tools. The green roof systems, which installed on different types of buildings, can put you on the right track to earning the highest BREEAM, LEED, DGNB or HQE certification ratings. Building certifications such as Leadership in Energy & Environmental Design (LEED) provide for certain tax credits of the green roof using and benefits for building owners.

Some implementations of the present invention. It pursues sustainable performance objectives while giving substantial importance to the life cycle analysis on a building scale and to the impacts of a project on health, comfort and the environment by using green roofs. The Department of Environment in Malaysia has been provided the water quality standards, practiced

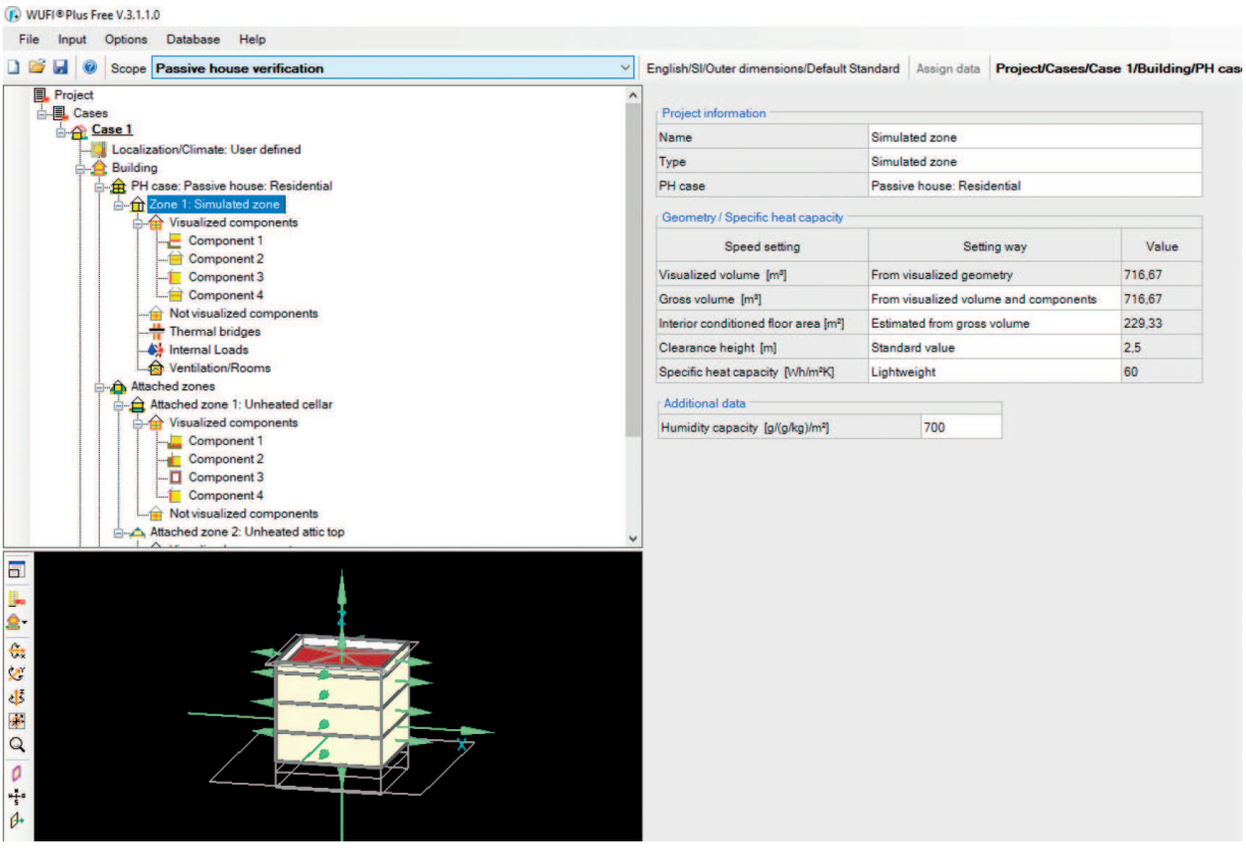

Figure 5. Evaluation of green building energy performance.

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water quality standards for green roof installation. According to standard NWQS, there are six classes of water quality (I, IIA, IIB, III, IV, and V) and this classification is based on a descending order of its best quality to the worst quality [6]. The rainwater quality parameters are estimated by soft computing technology like adaptive neuro-fuzzy inference system.

Following the same pattern, the Karlsruhe Performance Rating System rates green roofs according to natural categories. These functions, which assigned a weight based on its importance are as follows:

1. Type and depth of soil used (Soil)—15%.
2. Impact on climate due to evapotranspiration (Climate)—15%.
3. Type and variety of vegetation (Flora)—30%.
4. Impact on zoological biodiversity (Fauna)—30%.
5. Average annual stormwater retention (Water Balance)—10%.

The sum of the weighted rating for each of the five functions is used to compare different green roof systems and stipulate minimum requirements.

2.2. Analyses of green roofing structures

The device of the green roof means the creation of structurally complex systems with vegetation and soil mixture placed on the waterproof membrane, with the integration of irrigation systems, as well as devices that convert solar and wind energy.

The green roof principles that exist today are manufactured in Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) landscape industry organization in Germany. "The Guidance on planning, execution and the maintenance of green roofs"—version of FLL on English language. This document covers design, construction and maintenance of green roof systems, with detailed sections on stormwater considerations, requirements for the plantings, growing medium, drainage and requirements for all green roof "pie" layers. It also provides information on testing some components of the green roof. The green roof represents a multilayered structure and consists of several layers: a vegetative layer, a soil substrate, a filtering layer, a drainage system, a layer of waterproofing and a layer of thermal insulation. According to the standard TGRCS – Toronto Standard "Construction of green roofs," the green roof "pie" is shown as a multi-component structure (**Figure 6**).

In this chapter, each layer is examined for the analysis of the selection of the material of the roofing system and its features. The materials used for the construction of roofing surfaces must meet the requirements of the current standards in the field of standardization and green roofs types: intensive, semi-intensive, and extensive roofs. The vegetation is selected individually according to the climate conditions, the roof location and the thickness of the growing medium. Often, mosses, lawn grass, wildflowers and mountain vegetation are chosen for the green roof covering, since such vegetation is not whimsical to specific climate and regional conditions.

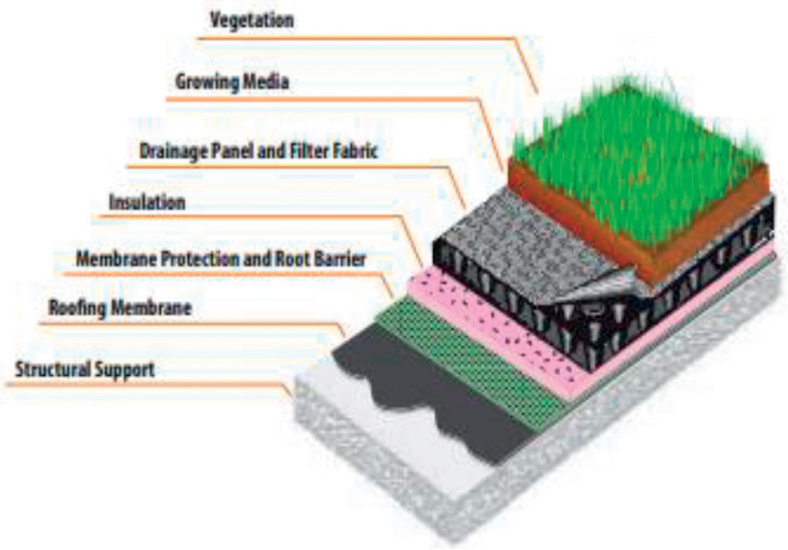

Figure 6. The structure of the layers of the green roof "pie".

The growing medium is usually soil substrate or natural soil. Reduce the weight of the layer can effectively be due to the addition of loose fillers (peat, sand, and unlimited additives). The soil depth is selected in accordance with the type of green roof: intensive or extensive types.

As a filter layer, a nonwoven material is used—geotextile. In this study, the analysis of the two most popular methods of bonding—needle piercing and thermal calendering—is given. According to the roofing technology, the thermally calendered geotextile is stronger for tearing than needle-punched. Thermally bonded geotextile, unlike needle-punched, has the property of high wear resistance and excellent tensile strength. The material is resistant to the effects of ultraviolet rays and aggressive media, such as atmospheric moisture, acids, alkalis, bacteria or fungi.

The drainage removes excess water from the soil. In the drainage layer, polystyrene pellets are used. The most resistant materials for the anti-root layer are fiberglass, membranes made of synthetic material are also used. In case of green roof modules, the growing medium is separated from the drainage by a permeable geotextile fabric which is responsible for blocking soil penetrator. Research considered the wider multiple solutions both Sustainable Urban Drainage System (SuDS) and Green Infrastructure (GI) as management solutions containing natural elements and estimate their physical interdependencies with other city scale infrastructure, in parallel to this the interactions between the various agencies responsible [7].

In UK practice, Sustainable Urban Drainage Systems are configured as a sequence of stormwater practices and technologies used to drain stormwater in a manner of replicating as closely as possible the natural, pre-development drainage from a site, consistent with the previously-described principles [8].

The function of the waterproofing layer is to protect and prevent water and moisture from entering through the structure inside the building or onto external walls. As a waterproofing layer, a bituminous polymeric material should be used, laid in several layers:

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- polymer waterproofing membranes on bitumen (EPDM) basis with anti-root protection, environmentally friendly material; or polymeric waterproofing membranes on a synthetic (PVC-membrane) basis with anti-root protection with life cycle up to 60 years;
- additional copper or aluminum foil layer to the membranes;
- liquid rubber;
- polyethylene film.

If the roof is flat, then the waterproofing is arranged with a slope of 3–5% to ensure the necessary flow of water. It is recommended to make a heat-insulating layer of foam glass or pearlite sand. Also as a heater apply extruded polystyrene plates and mineral wool. The thickness of the insulation of the coating is established by calculation, taking into account the heat-insulating properties of the remaining layers of the coating.

The design of the intensive green roof differs from the extensive type. Insolation is located not on the bottom, but on the top of the waterproofing membrane, which protects it from mechanical damage. In this case, the required angle of inclination of the roof for the device of the green roof is 5–8°. With an increase in the slope of the roof more than 12°, it is necessary to arrange transverse locks: wooden planks, geogrids or cassettes, which will hold back the soil. With the use of devices that prevent soil from slipping, planting of greenery on roofs with an angle of up to 45° can be established. In modular green roof systems, the basic element is a tray that quickly and easily mounted in a single covering. This system can be used on roofs with a slope of up to 20%.

These recommendations are given for choosing the most energy-intensive and economical structure of the green roofing system. A detailed analysis of the multilayer material structure and labor analysis of the green roof installation is presented the main features of using greening systems on roofing structures.

In some studies, it is noticed that in Finland forests represent an iconic national landscape and novel green spaces meeting the needs and preferences of urbanites are considered increasingly important to produce livable urban environments.

3. Conclusion

Nowadays smart solutions of green roofs are becoming more and more popular in recent times for their ecological, technical, economic benefits and esthetic qualities. Successful urban planning is including network of natural and semi-natural areas that integrate green roof systems into natural constructed urban environments. In the meantime, existing green roof technologies can be expensive to purchase and labor-intensive to install. This research is aimed to contribute to sustainable future-oriented solutions for the complex problems of urban areas to create livable ecosystems. The renovation project of roofing structures includes apparatus and method for green roof system to install on a rooftop on the residential, government, public and commercial buildings, trade and office centers. Modular green roofs in urban ecospace is an

emerging trend in green building development. Innovative energy-efficient green technologies will bring a great benefit to the ecology and help to relieve the Heat Island Effect, in light of growing concerns about climate change and greenhouse gas emissions (GHG). Eco-trend of Modular green roofs refer to rejuvenate and rebuild the nature. Although this study has made several advances in predicting benefits of green roof systems, and it has to move further on work pertaining to green roofs, there are several areas that will require further researching.

The relevance of the research topic is determined by the need to develop an effective, economically progressive technology for the device of inversion roofing systems by landscaping. With increasing density of development of urbanized areas, technologies of construction of exploited roofing coatings are of particular importance. Existing technologies for roofing coverings do not allow you to perform the required amount of work of adequate quality and are characterized by low productivity, as well as high labor costs. The predominance of green plantations on the coverings of buildings and structures contributes to the formation and development of new urban space, improves the environment, reducing emissions of greenhouse gases into the atmosphere. Total reduction of greenhouse gas emissions by 52.3 million tons CO_2 by 2020 characterizes the increase in the level of environmental safety of the city.

The modern modular technologies in the construction of roof coverings with landscaping systems are the most effective solution, as the labor intensity of technological processes during the installation of roofing systems with landscaping systems is reduced compared to traditional types of roofs, and functional development is provided for the exploitation of the roof. Innovative solutions in the creation of engineering systems are the devices that convert and store solar and wind energy on the green roofs of buildings and structures. At present, energy has received serious prerequisites for development, so green roofs with the integration of renewable energy sources are key elements on the path of innovative development of green building technologies both in Russia and abroad.

In Norway, approximately 90% of individual housing projects are equipped with roofs in operation. At the same time, landscaping systems are actively used on roofing in the United Kingdom, Denmark, and The Netherlands. The leader in the field of green building technologies is Germany, the "Green capital" of Europe, where the standard of quality of the device of green roofing on buildings has already been developed and applied. In the earliest researching [9], measurements in Germany conducted in 1984 revealed not only reduction in maximum surface temperature but also temperature amplitudes reduced by half due to green roof installation. Furthermore, adding green roofs to urban environments provides eco-restorative habitats and affords unique protection from traffic noise in the city (**Figure 7**).

Modular green roof systems in urban ecospace are becoming increasingly important part of the green building renaissance. Modular green roof constructive system is regarded as the most effective solution of innovative approaches and techniques for green design and construction. Trying to find the optimal system of a green roof, this system is to be solved various problems of roof covering by making inexpensive, little expenditure of the labor and waste-free green roof assembling based on the principle of building kit. The unique configuration of the system with an unusual combination of architectural and esthetic design solutions gives a beautiful appearance to the urban areas and also allows to use methods of landscaping on

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Figure 7. Green roofs as eco-restorative habitats in the city.

living roof. Given the increase in urbanization worldwide, the impact of urban green spaces on future generation have aim to save our Green Planet and bring great benefit to the ecology by develop green building technologies. This future-oriented green roof solution is appreciated by potential investors because implementing this system can improve a company's competitiveness and bring multiple economic profits and great environmental benefits.

Author details

Elena Korol* and Natalia Shushunova

*Address all correspondence to: professorkorol@mail.ru

National Research Moscow State University of Civil Engineering, Moscow, Russia

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