Implementation of Sustainable Technology of Green Roofs for Renovation in Moscow

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Abstract. Metropolis cities like Moscow, have a very important part in social and economic growth of countries like Russia for example. But neglecting environmental resources and the impact on climate change have become a serious challenge for realization of the contribution which those big cities can make on economic development of the countries. This article contains a technical suggestions how to reduce the negative environmental consequences of the daily life of the megalopolis, new technological methods of urban planning and landscape architecture are being implemented all over the world. This article considers the new environmental methods and best foreign practices for the transition towards sustainable cities. Further described the possibility of using innovative technology of green roofs especially for Moscow region. The article is considering green roofs as a very effective mechanism for reducing the heat island effect and for “precipitation management”. This article gives a short overview of the European expertise of using green roofs for climate-change-adaptation measure and gives recommendations to Russian environmental policies.

1. Green and sustainable cities

Metropolises play an important role as drivers of the economy of a region and country, as places, connecting people, giving them inspiration and places for creativity and innovation, and as sources of an array of different services for their suburbs and neighborhoods. Because of their high density, cities have a huge resource for saving energy and should become a driver for a carbon-neutral economy.

Today, more than two thirds of planet’s population live in towns, cities and metropolis areas. Most of them face a very similar number of environmental challenges and growing risks, including, but not limited to appalling air quality, huge levels of noise, greenhouse gas (GHG) effects, water shortage, soil contamination, brownfields and problems in efficiency of the main resources.

These risks and challenges require enormous budgets, with the result of massive inadequacies in the usage of valuable and limited local resources, when the most poor and most underprivileged people suffering more than other. Because of this, preparation for natural disasters through risk assessments, participatory design of spaces, creating green infrastructure networks and changing the
building regulations is required to increase urban sustainability in the event of environmental related disasters.

There is a positive case in Western Europe - one of the procedure instruments the European Commission is currently using to address these challenges is the European Green Capital Award (EGCA), which recognizes and rewards local efforts to improve the environment, economy and quality of life in cities. The EGCA is awarded each year to a new European city, which is leading in environmentally pleasant urban way of living and which could be regarded as a positive case and real role-model to inspire other places in Europe. Cities vary enormously and sharing these specific examples of what a European Green Capital could look like is very important if further progress is desired.

The EGCA is the best European case resulted from an initiative, in which 15 cities are currently involved (Helsinki, Warsaw, Riga, Tallinn, Kiel, Berlin, Madrid, Prague, Kotka, Dartford, Tartu, Ljubljana, Vienna, Vilnius and Glasgow) and the Association of Estonian cities on 15 May 2006 in Tallinn, Estonia [1]. This “green dream” became into a reality when a Memorandum of Understanding establishing this progressive award was finally published by the European Commission in 2008 to recognize those leading cities with environmentally friendly urban living.

2. Urban planning and green infrastructure

Thoughtful landscape and urban planning could become major tools for urban adaptation and mitigation measures. Urban green fabric, public transit networks and combined heat-electricity systems are some of the planning concerns that have long been considered to be the main tools to reduce city energy concentration. Landscape planning and green infrastructure design are also a powerful instruments in identifying risky sites and for providing spatial solutions to safeguard urban environment [2].

Construction industry is one of the priority sectors of economy in relation to green infrastructure and climate change. In this green and carbon neutral urban environment buildings are to be modernized in a way to become as energy-effective, healthy and sustainable as possible; all new construction should be required to be ‘net-zero’ or ‘plus-energy’ by local normative acts or so called “green standards”.

This standards are often created on the basis of life-cycle principles, when the construction materials and end of service disposal or re-use are assessed. Building companies and real estate businesses operate in a basis of solid encouragements to provide zero-energy results. Buildings have to be maintained by a well-developed upkeep business. Green planning regulations prevent unwanted cities growths and guarantee spatial incorporation, preventing social seclusion and social disproportions. Construction in sensitive areas should be monitored and, if necessary, security actions are assumed.

The so called framework of urban green and blue (water) belts functions as the ecological structure for any city environmental sustainability and general quality of life. It is an important part of a micro-climate management policies. In this case, urban forestry spaces creation and well-management and existing habitat preservation are the simplest and low-price ways for carbon dioxide reduction and air quality improvement. Creating a sustainable urban green framework is also a key factor for reducing the heat island effect in the cities through evaporative chilling and shading created by tree canopies to design cooler microclimatic zones. This will bring a greater effect when done on a city scale. Water runoff management is another important issue to be considered in any city green framework, as it lessens the risks of flooding of the paved areas, soothes droughts and greatly reduces heat waves.

The green city infrastructure (often referred in Russian texts as “green skeleton”) should be designed as a continuous network of green spaces, corridors, small and large parks, boulevards, even an ordinary street tree-planting, and could also consist of a variety of different elements, such as urban forests, green grass areas, water features, swamps and wetlands. Any means of increasing the green biomass of the city should be used, including creation of special administrative regulations for green
roofs installation and converting neglected sites into landscaped areas. Green roofs with sustainable vegetation are becoming as an important part of a modern smart city green infrastructure.

3. Standards for green roofs (international experience)

Not that many countries or local authorities have regulations, standards or policies on green roof design and construction. The oldest guidelines in the world, which were first printed in the 1992, are German regulations called “Guidelines for the planning, execution and upkeep of Green Roof sites” [3] (Dachbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltung von Dachbegrünungen) published by The Landscaping and Landscape Development Research Society e.V. (FLL - Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V) in Bonn (Germany). [8] This green roof guidelines well define the typology of different green roofs (extensive, intensive and semi-intensive), several vegetation categories, standards for the construction techniques, as well as maintenance requirements. Since their first edition, they have already been published several times with the new Guidelines published quite recently in 2018.

This kind of policies could be a real working mechanism, which can be used by city authorities to demand any developer or an investor in the construction industry, to use special “standards”, or make necessary ecological actions, to include a biodiversity in any city new project, to be definite that natural elements and generally speaking green biomass can be enlarged. Local authorities, using this Guidelines could add necessary specific issues to the base policies, with extra papers with figures, graphics, tables and pictures, based on a local research, in order to localize the documentation to deliver much bigger local aspect about green roofs.

The GRO (the Green Roof Organization) Code has been established in the United Kingdom to guarantee the green roof system producers provide excellent quality products for the landscape market. Contrasting to many other different construction products, green roof systems depend on both an engineering and a biological group of requirements in their design, implementation and after care procedures. The GRO Code include a comprehensive description issues on all aspects of planning, installation and maintenance. [9]

It is also important to notice that there are presently two countries in the world that approved a very concrete standards—Switzerland and Austria.

The standards SIA (the Swiss Society of Engineers and Architects) 312 for green roofs were published and printed in November 2013. [10] SIA 312 is a very technical strong paper, which is full of very detailed and comprehensive rules, describing it’s user starting with the main section of project research, design, using correct materials and construction. Its philosophy is based on excellence in terms of designing and building quality green roofs. If planned the right way, green roof could be covered with the sustainable vegetation layer, with the recycled materials, and the fauna and flora to be very diverse in the long term. For the first time, environmental reimbursement mechanisms and requirements were incorporated in a country standard in Switzerland.

At the moment the Russian Standard (GOST) is being developed within the country system of “Green Standards” by Moscow State University of Civil Engineering (National Research University). It will include both ecological and technical requirements for design and built spheres. The standard will contain the typology of green roofs, based on different vegetation typology, requirements for the building techniques, green roof procedures, maintenance and safety requirements for Green Roofs. The standard is planned to be published in 2019.

4. The benefits of green roofs technology

Rooftops should become important part of urban green infrastructure; they could largely improve the city environment by placing landscaped areas on the roofs, especially in the most urban and dense regions of the metropolises, even on the underground garages like in Toronto, Canada (Figure 1). The values of green roofs are various. They could balance and sometimes control storm water runoff, minimize carbon dioxide in the air, conserve building energy, increase general biodiversity (by not only plants, but insects and other living creatures), regulating the city heat island effect, and reduce
noise levels and dust. Green roofs increase the lifetime of waterproof membranes, decrease flooding levels, give city authorities additional jobs, and reduce heating and air-conditioning charges. They also offer educational and therapeutic solutions, proved landscaped areas for recreation and urban agriculture, and can strengthen communities (Getter & Rowe, 2006; D. HUI, 2006; Oberndorfer et al., 2007; Stovin, Dunnett, & Hallam, 2007; Susca, Gaffin, & Dell'Osso, 2011; Van der Horst, 2013; L. J. Whittinghill & D. B. Rowe, 2012) [3]. This is just a short summary of their ecological bonuses, although it is not an inclusive list.

4.1. Reduction of amount of city storm water run-off

Perhaps the largest environmental benefit that green roofs provide is the greatest reduction of amounts of clean rainfall water run-off. All green roof systems are capable to keep so much water of the rainfall, which is normally captured in the substrate, drainage layer or plants, and will slowly vaporize from surface of the substrate layer or will be evaporated again into the air bit by bit by means of transpiration [3]. Water storage capacity of a green roof depends on many specific project factors such as substrate depth, its structure, and plant communities and varieties, as well as climatic factors, such as rainfall. Because green roofs are capable to keep a lot of rain water, they can moderate the effects of impermeable surface run-off. For instance, let’s calculate when 6% of the total roof area in the city of Toronto, Canada, were landscaped, Peck (2005) assessed that the effect on storm water storage would be identical to construction of a $60 000 000 Canadian dollar storage tank [3, 4]. In Toronto, generally, green roofs are recently acknowledged as a best management practice for storm water regulation. Recently, special city guidelines are produced by Toronto Water Company. This means that when a green roof project is designed, it will be considered part of a new development’s overall storm water management plan.

Figure 1. Green roof on the garage, Toronto, Canada.
4.2. Energy conservation and the urban “heat island”

Green roofs greatly increase waterproof membrane’s lifespan; they also provide additional thermal insulation for the building, consequential in energy savings and decrease of the city heat island effect. Depending on various substrate depths, additional shade from vegetation and transpiration power of plants can reduce energy effect from sun by up to 80% compared with non-landscaped roofs. Green roofs have noticeably lowered interior temperatures degrees 3 to 4 C, when outside temperature was fluctuating between 25 Celsius and 30 Celsius (Peck et al., 1999) [3, 4]. Every reduction in building internal air temperature by 0.5 C could also economize electricity consumption for air-conditioning as much as up to 8% (Dunnett and Kingsbury, 2004) [3].

When buildings and structures consume 35 percent of entire energy and 64 percent of total electricity use, green roofs execution on a global city scale could significantly impact on total energy savings (Kula, 2005). In another research Laberge (2003) assessed that for the Chicago Major office, the USA, economy of energy a could become in 4000 USD per year for the heating system and air-conditioning combined [3].

In warmer and moderate climates most energy savings from landscaped roofs will happen throughout summer season. That happens for the reason that the insulation qualities of the substrate layer are much bigger when there are spaces between particles of substrate and there is air in the pores on a contrary to the cases when they are filled with water and ice, which is usually the case in winter season [3].

NASA scientists have realized that green roofs deliver a much cleaner city areas and energy savings [5]. NASA conducted its first case study in 2003, which have proved that UHI effects could be lessened by substantial green roof construction. As main part of this case study, they have measured various situations for green roof landscapes, ranging from 20% to 50% by size. The calculations showed that when constructing an extensive green roof, it would reduce summer surface temperatures by as much as 1.6 degrees Fahrenheit (F).

4.3. To rise biodiversity and deliver sustainable habitats.

Extensive types of green roofs are normally not accessible to the general public. Therefore, they offer peaceful habitat for plants, microorganisms, insects, and birds. An excellent case could be seen in Zurich central train station (Figure 2), where such extensive habitats were created for lizards. City council gave planning permission for the extension of the station platforms only subject to those habitats for the local lizard communities being built on top of the every platform roof. In a different biodiversity case study of 17 extensive roofs in Chicago city hall), “insects hotels” and many other inventions to increase biodiversity.

Virtually every green roof can provide place for additional habitat. In Dearborn, Mich., the USA there is one of the world’s biggest green roofs, on top the building of plant of Ford Motor Company. The 42,900 m2 extensive roof contains of a mixture of 13 Sedum varieties, planted in less than 76 mm substrate depth. After 2 years of completion of this project, when the plants community has fully established, there were identified 29 different varieties of insects, seven different varieties of spiders, and two interesting species of birds (Coffman and Davis, 2005) [3].
4.4. Improved aesthetic quality
When people watch landscape areas, plants and natural sites, it has been proved to have medical advantages and positive effects, like those which reduce mental stress, decreasing blood pressure, liberating tension of muscles, and generating positive feelings and optimistic emotions (Ulrich and Simmons, 1986) [3]. Described advantages can be interpreted as health improvements and greater job efficiency. Kaplan (1988) has written, that workers who had a pleasant natural environment, such as trees, shrubs and flower beds, were less stressed, feel greater pleasure from their work, and informed lesser headaches and different illnesses, than those who had no view of landscape. Ulrich (1984) discovered that patients are recovering much faster from operations when they have a view of a green landscape. And it is not only matter of aesthetics of a landscape area, but property-owners could often increase rental rates and hotels are able to charge much more fee for a “‘interior with a nice landscape view” on a contrary to traditional gloomy roof background.

4.5. Mitigation of air pollution
Vegetation on a green roof (intensive and extensive) can absorb and filter dust particles and other different pollutants in the air. Particles will ultimately be drained into the substrate through rain fall, and most of them will be immersed in a green plant leaf tissues. A great diversity of aerial pollutants can be improved by green roof plant communities. A German case study confirmed that green roof plants can considerably decrease air pollution created by diesel vehicles (Liesecke and Borgwardt, 1997) [3]. Another researches Yok Tan and Sia (2005) discovered that a 37% and 21% decrease of sulfur dioxide and nitrous acid respectively directly on top of any constructed green roof. Peck and
Kuhn, 2001 have assessed that plant communities on green roofs can eliminate dust elements of 0.2 kilogram of particulates every year per square meter of landscaped surface[3].

4.6. Noise reduction
All hard surfaces (like pavements, roofs, roads, etc) in urban environment reflecting a lot of sound. But, on the contrary, green roofs plant communities absorb sound waves depending on the character of the substrate and type of the vegetation and varieties of plants. On the huge roofs of the Frankfurt airport, Germany, there is a 10 centimeters system of extensive green roof is reducing levels of noise as much as by 5 dB (Dunnett and Kingsbury, 2004) [3].

4.7. Energy and environmental design (LEED) standards
Green roof construction will also allow the developer to achieve additional credits in the LEED system assessment, an accreditation system implemented by the US Green Building Council. It is an organization that stimulates “the design and construction of buildings that are environmentally responsible, profitable, and healthy places to live and work” (US Green Building Council, 2005, p.2). [3] Assessment system LEED was developed to launch standards and policies for design and construction industry. This system reduces the negative effect that buildings have on the city environment and people.

Following its guidelines, having done a good quality green roof project, a developer can receive up to 15 LEED credits in the following categories: sustainable places, water efficiency, energy conservation and atmosphere cleaning (Kula, 2005) [3].

4.8. Social benefits
Green roofs and all landscaped areas, offer a good solution to the city residents, give them a great chance to interrelate with natural environment, offer a feeling of emotional comfort and security. As the traditional city parks, green roofs can offer people a much improved quality of life. Many intensive green roofs are done with benches, playgrounds, sport facilities and water features to improve social communication and give residents a sense of community with much greater social interaction.

5. Green roof potential solutions for Moscow
Very high concentration of population and diversified activities in a very limited area of the city lead to a large-scale environmental impact of the entire urban infrastructure on the environment - not only in Moscow, but also in many suburban areas of Moscow region. These circumstances required a comprehensive and competent approach to the implementation of environmental measures in the metropolitan area.

Summer surface temperature there is much higher than nearby forest or agricultural areas in the suburbs with a high number of green areas. This is widely known fact “the city heat island”. Absorption of the sun’s energy by concrete, asphalt and paved street surfaces is much higher. This is also true for the vehicles and for any structure with dark painted building roofs and facades, which absorb energy during the day time and by large buildings which keep heat from releasing it into the sky at night. The volume of heat emitted by city facilities allows us to talk about the thermal pollution of Moscow. Especially bright “heat island” expressed in the central part of the city, where the average temperature is 1.5-2 °C higher than surrounding areas.

Energy efficiency and reduction of greenhouse gas emissions are one from the key directions on the way of reducing the negative impact on the climate. Moscow, as like other major cities in the world, conducted a number of activities for sustainable and range of measures for transferring urban economy to energy efficient technologies to reduce their contribution to climate change and edition to the expected climate change. Also Moscow has the State program for the city of Moscow "Development of municipal engineering infrastructure and energy saving” for 2012-2018 aimed at improving energy efficiency is being implemented.
Green roofs can contribute to the successful implementation of this program. To achieve greater effect for the city could be developed a program of green roofs with a multiplier effect (Figure 3).

Figure 3. Green roof of office building Sheremetyevskaya, 34, Moscow.

As best practice example we can consider the policy of London’s authorities with regards to green roofs. It was an initiative of Boris Johnson, ex-Mayor of London, to incorporate living roofs and walls in new development projects in the city. According to the report of European federation of green roofs, from 2004 approximately 1 000 000 m² green roofs were installed in London. Annually about 100 000 m² a new green roofs installed in London. GLA report showed, that 32% Central London roofs could be potentially greened.

This experience of creating green roofs in Central London we can try to apply for the center of Moscow.

Let’s take Central administrative district (CAD) of Moscow into consideration as an example. The amount of green spaces there is very limited - according to Moscomarchitectura (2013), amount of green areas in CAD was 3,55 m² per person, although the average figure for Moscow is about 21 m² per person. The total area of CAD is 6 627 ha. The footprint area (covered with buildings) is about 1500 ha. This could give an estimation of the total roof space. The expert estimation is that about 5% of these roofs could be covered with vegetation. And if so (even not to take into account 32% of London’s potential) the city of Moscow could get an additional of 75 ha of green space in the centre of Moscow. This could be compared to 5 new city parks of the size of recently opened Zaryadye park.

The technology of green roofs is also planned to be used in the renovation project in Moscow. Here we would like to present a possibility of green roofs for Kuzminki district. The total area of the projected district is 109,65 ha. The amount of green areas in Kuzminki is 18 m²/person. Even if the half of the roofs would be planted the area would get an additional of 5 hectares of green space.
6. Conclusion

Designing and building green roofs is one of the most powerful approaches to respond to the challenges which we face with the damage done to the natural habitats in our built environment. In my research I have acknowledged those environmental benefits, that green roofs can offer, such as energy saving, thermal insulation, providing greater biodiversity and places for development of natural habitats, social and aesthetical bonuses, noise and air pollution reduction. I have presented two potential areas in Moscow to use this technique.

Roofs in general, being quite normally unused, gloomy spaces and taking a huge proportion of city space, could become ecological oases and nicely landscaped areas, a part of a city green infrastructure, they will do their job to reclaim degraded habitats, which were lost as a result of construction and finally improving people’s quality of life.

References
[1] Urban Environment Good Practice&Benchmarking Report European Green Capital Report 2017 pp 8-9
[2] Climate Neutral Cities United Nation (New York and Geneva) 2011 pp 28-30
[3] Getter K L, Bradley R D 2006 The Role of Extensive Green Roofs in Sustainable Development HortScience 41(5) pp 1276-1285
[4] Mitrovic S 2010 Action Plan for Sustainable City of Toronto Case Study of Green Roofs Presentation for 46th ISOCARP Congress 2010 Nairobi
[5] NASA Green Roofs Research July 2012 pp 4-6
[6] Telichenko V, Benuzh A, Mochalov I 2017 Landscape Architecture and green spaces in Russia MATEC Web of Conferences 117 00164
[7] Telichenko V I, Benuzh A A, Mochalov I V 2017 Using of green roof technology on buildings for creating a comfortable urban environment Realty: economics, management 1 pp 30-33
[8] https://www.fll.de/
[9] https://www.nfrc.co.uk/green-roof-installations
[10] http://www.sia.ch/en/the-sia