THE IMPACT OF THE BUILDING ENVELOPE WITH THE GREEN LIVING SYSTEMS ON THE BUILT ENVIRONMENT

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Altering the surface cover of an area causes the change in the environment. By erecting buildings change in the flow of energy and matter through the urban ecosystems occurs creating multiple environmental problems. Built areas exert considerable influence over their local climate, amplifying problems such as heat waves, air pollution, and flooding. Greening the building envelope these problems can be partially mitigated. By combining nature and built areas in their designs, architects and urban planners can respond to these serious human health and welfare issues and restore the environmental quality of dense urban areas. Green living systems are not the only solution for new designs. Retrofitting existing buildings by altering the buildings' surficial properties can reduce buildings' energy consumption in case of older buildings with poor existing insulation. Implementation of green living systems in the building envelope, greening horizontal surfaces with intensive and extensive green roofs or using vegetation in vertical greening systems for façades, is a strategy that provides ecological, economic and social benefits.

This review paper presents collected evidence of effects and explores the important role that the green living systems can play in the dense urban areas. Benefits such as heat island amelioration, reduction of buildings energy consumption, air quality and indoor and outdoor comfort conditions improvement, stormwater management and improved water run-off quality, will be mainly considered.

Key words*: green roof, green wall, building, energy, environment*

1. Introduction

Urban areas detrimentally invade natural landscapes impacting the entire planet, more than 50% of the human population is nowadays residing in cities and it is predicted to rise up to 70% in 2030. According to The Energy Performance Building Directive 2010/31/EU (European Parliament and Council of the European Union, 2010) residential and commercial buildings account for a high rate, between 30% and 50%, of worldwide total annual energy consumption. Also by the year 2030 average global air temperature rise of 2°C is predicted. The continuous temperature increase in the cities, affected by the undeniable climatic change, is escalating the energy problem of cities and amplifying the pollution problems. The thermal stress is increased, thus both the indoor and the outdoor thermal comfort levels are decreased and health problems are enhanced. The optimization of buildings performance and enhancement in the green infrastructure are the key issues to reduce global energy demand and provide cleaner air and water, while improving living environments.

Greening the building envelope is innovating technology in architecture that can regain losses of natural environment produced by erecting buildings. Adapting the existing building envelope into a green living system is an efficient and sustainable solution for improving the environmental balance of cities and limiting the major negative effects of urbanization providing better comfort at building and urban level.

2. Green Living Systems

Living architecture is the integration of living, organic systems characterized by green walls and green roofs, with inorganic and lifeless structures that have come to dominate modern architecture. It is multi-disciplinary, compounding the knowledge of architects, landscape architects, urban planners, engineers and biologists.

2.1. Green living walls

Green wall technologies may refer to all forms of vegetated wall surfaces. Two major categories can be identified: Green Façades and Living Walls.

2.1.1 Green Façades

Green façades are a type of green wall system in which climbing plants or cascading groundcovers are trained to cover specially designed supporting structures (Figure 1.), rooted at the base of these structures in the ground or in intermediate planters. Technological innovations in Europe and North America have resulted in the development of trellises, rigid panels and cable systems to support vines and aggressive plants that can damage unsuitable walls, while keeping them away from walls and other building surfaces. The plants typically take 3–5 years before achieving full coverage.

Figure 1. The Green Façade Singapore Changi Airport Terminal 3, Singapore, Singapore

Figure 2. The Living Wall Europa Congress Palace Convention Center, Vitoria-Gasteiz, Spain

2.1.2 Living Walls

Living wall systems are composed of prevegetated panels, vertical modules or planted blankets that are fixed vertically to a structural wall or frame (Figure 2.). These panels can be made of plastic, expanded polystyrene, synthetic fabric, clay, metal, and concrete, and support a great diversity and density of plant species

Due to the diversity and density of plant life, living walls typically require more intensive maintenance, due to fertilization and irrigation, than green façades.

2.2. Green living roofs

The model of the green roof consists of three main components: structural support, soil layer and foliage layer. The structural support includes all the layers between the inner plaster and the drainage layer or filter layer. In most cases the structural layer is treated as a single layer with constant thermal properties and the specific value of thermal conductance. The soil layer is complex consisting of the solid phase (organic and mineral material), the liquid phase (water) and the gaseous phase (water vapor and air). The foliage layer (canopy) is composed of the leafs and the air within the leafs.

Green roof construction mimics in a few centimeters what normal soil does in a couple of meters. The green roof accomplishes the natural balance through several layers, beside the three main layers, depending on its complexity. The drainage layer provides water for upper layers in relatively small space and with light weight. Excess water overflows and easily passes underneath it away and down the roof drain. The growing medium, filter and protection layer act to support plants and protect lower levels. The foliage layer depends on the plant selection.

There are two main classifications of green roofs: Extensive Green Roofs (EGR) and Intensive Green Roofs (IGR).

2.2.1 Extensive Green Roofs (EGR)

Extensive Green Roofs are lightweight structures with a thinner substrate and feature succulent plants like sedums that can survive in harsh conditions (Figure 3.). Extensive roofs are used mainly for environmental benefit, require little maintenance once they are established and are generally cost effective, particularly in commercial and public buildings with long life spans.

Figure 3. EGR, Headquarter Honda, Clermont, FL, USA

Figure 4. IGR, Delft University of Technology Library, Delft, The Netherlands

2.2.2 Intensive Green Roofs (IGR)

Intensive Green Roofs allow a greater variety and size of plants such as shrubs and small trees but have higher initial costs. Having a thicker soil layer should be considered as a landscape with plants found in parks and gardens and may require irrigation during dry periods. Because of their thicker soil, intensive roofs require greater structural support than extensive ones (Figure 4.).

Characteristics and variations of green roofs are shown in Table 1.

Table 1. Characteristics and classification of green roofs

	Extensive	**Simple-Intensive**	**Intensive**
Soil depth [cm]	4 to 20, 10 to 15 typical	10 to 50	10 to 200 +
Plant heights [cm]	5 to 30	30 to 60	30 to 90 +
Roof slopes	Slopes up to 30 degrees	Only used on low slopes or terraced roofs	Only used on low slopes or terraced roofs
Irrigation	No	Periodic	Regular
General weights [kgm^{-2}]	60 to 145	120 to 195	170 to 500 +
Use	Ecological protection layer; Usually non-accessible	Designed Green Roof	Park-like Garden; Designed for access (typically)

3. Environmental benefits provided by the Green Living Systems

Besides adding aesthetic values to the environment, the functional benefits provided by the Green Living Systems address a number of environmental, economic and social issues arising from increased urbanization. Numerous research studies show that they increase thermal efficiency, provide reduction in stormwater runoff and improve stormwater quality, reduce interior noise levels, help reduce dust and air pollution levels. Depending on the types of plants and soils, a green roof can provide natural habitat for animals, insects and plants and can help increase the biodiversity of an urban area.

3.1. Energy savings obtained from Green Living Systems

Possibility to cool the ambient air is important phenomena of the green roof. This thermal benefit is result of the direct shading of roof surfaces and reducing solar heat gain through transpiration and photosynthesis by a foliage layer (canopy), which is composed of the leafs and the air within the leafs [1]. The direct cooling effect is proportional to the green area. Larger the greening area, the better is the effect on cooling and humidification. Measurements of the surface temperature in green roofs reported in [2], show that in places dominated by thick dark green vegetation surface temperatures are almost 10°C lower. The indirect cooling effect brought by the green roof is accomplished by using the sun's energy to turn water stored in plants, through transpiration, and soils, through evaporation, into water vapor rather than heat. Releasing a large amount of water vapor into the air increases the humidity level near the green roof [3]. The added thermal mass also helps to stabilize the internal temperatures and reduce the daily oscillations [4].

In the case of redesigned flat roof [5] the calculated value of heat transfer coefficient U was improved for approximately 0.01%, which is a very low value, but in the same time the calculated value of oscillation damping factor ν was improved for about 300%.

Green roofs have been proposed for energy saving purposes in many countries with different climatic conditions, but their cooling and heating potential strongly depends on the climate, plant selection and building characteristics [6]. In temperate North America, a cost-benefit analysis of an extensive green roof on a retail store found small, but significant, reductions in energy consumption [7]. Green roofs can decrease the surface temperature of the roof 30–60°C according to an experimental study conducted in Japan and over 60% of heat gain for a building could be stopped [8]. In subtropical southern China, less than 2% of the heat gained by an EGR during a 24h period in summer was retained by the plants and substrate or transferred to the building below. The rest was lost through evapotranspiration, reradiated to the atmosphere, or used in photosynthesis [9]. For a subtropical Mediterranean climate, office building in Athens [10], results showed that well insulated buildings offer very little energy savings with the addition of a green roof with heating energy savings of 8–9% and cooling energy savings up to 1%, whereas older buildings with no insulation can have substantial energy savings of up to 44%. Simulation of modeled single family residential and low-rise commercial buildings [11] showed that the energy savings effect in Toronto could be over $11 M from the combined effects of cool roofs and shade trees. Detailed study in Canada [12] showed that the daily surface temperature variation with a green roof was approximately 6°C compared to a variation up to 45°C occurring with a bitumen traditional roof. Even in its starting phase, green living roof with LAI (Leaf Area Index) close to zero during the summer period had the external surfaces heated less than the traditional flat roof [13]. The difference of 14°C, 16°C, and 18°C in 24 hour period for three types of green roof assembly was significantly lower comparing to the conventional roof where difference of 40°C in 24-hour period was consequential and could induce serious damage over time. In extreme climates with high snow in winters, implementing the green roof, significant reduction of the heat losses was recorded [14].

Many of the benefits of green walls are similar to those of green roofs, such as lower heat loads in buildings. In Hong Kong, covering a concrete wall with modular vegetated panels reduced exterior wall temperatures up to 16°C in summer [15]. In terms of internal wall temperatures, a difference of more than 2°C was recorded, maintained even late at night, indicating that green walls have significant ability to reduce energy consumption for building cooling. Differences in external wall temperatures up to 10°C between vegetated and bare concrete walls were reported at Hort Park in Singapore, where various green wall systems were assessed for their thermal performance [16].

3.2. Green roofs and urban heat islands

Urban Heat Islands (UHI) effects have been studied as a fundamental anthropogenic modification of the urban environment. UHI refers to the effect whereby near-surface air temperatures are higher in cities than in nearby suburban or rural areas. This effect is common in cities where natural landscapes, which absorb a significant portion of solar radiation to create water vapor, have been replaced with non-reflective surfaces that absorb most of the solar radiation and reradiate back into the environment as heat.

Factors contributing to UHI effects include urban ecology (less vegetation covering, thus reduced cooling from evapotranspiration), urban canyon geometry (reduction of outgoing radiative heat flux due to ‘heat trapping’ in street canyons), anthropogenic heat emissions (vehicular traffic and heating/cooling of built infrastructure), engineered building material properties (higher thermal capacity and storage), and hydrological changes (increased runoff due to impervious surfaces and heat transmitted to streams via urban runoff).

Study [17] shows that an increase by 10% of the urban green in Manchester, UK, could amortize the predicted increase by 4K, of the ambient temperature over the next 80 years. The cooling effect on the urban microclimate with green roof retrofits increases with the increase of the LAI. An average reduction in peak temperature up to 0.4˚C and 0.7˚C for green roofs with a LAI of 1 or 2 respectively was found in Toronto study on the pedestrian level [18]. Reversely, at the rooftop level, the cooling effects were larger. Peak air temperature reductions of 0.4˚C and 0.8˚C during the day and of 1.1˚C and 2.0˚C at night were found. These results are comparable to those found in only a few available studies aiming to evaluate the heat island mitigation potential of green roofs on a city scale. The main characteristics of those mitigation studies are summarized in the Table 2.

Table 2. Existing studies on the mitigation potential of green roofs [18]

City	Research type	Roof Type	Results
Chicago, Us	Simulation using the Weather Research and Forecasting Model	EGR	Urban temperatures during 19:00–23:00 were 2–3K lower compared to the temperatures simulated without the use of Cool roofs.
New York, Us	Simulation using MM5	EGR	Peak temperatures at 2m height decrease 0.37–0.86K, while daily average temperatures decrease between 0.3–0.55K
Tokyo, Japan	Simulation using the CSCRC model	EGR	Almost negligible impact because of the height of the buildings where green roofs are installed
HongKong, China	Simulation using the EnviMet tool	EGR	Almost negligible impact because of the height of the buildings where green roofs are installed

When vegetative roofs are installed in high rise buildings, their mitigation potential is almost negligible, but when the building height is lower than 10m green roofs are the most effective solution. A green living systems covering 50% or more of building envelope, when implemented in coordination with other green infrastructures, like street tree planting, could result in city-wide cooling throughout the day and during peak summertime energy demand periods.

3.3. Stormwater Amelioration

Green roofs store rainwater in the plants and growing mediums and evaporate water into the atmosphere. The amount of water that is stored in a green roof and evaporated back is mostly dependent on the growing medium, its depth and the type of plants used. The ability of an extensive green roof to prevent stormwater runoff depends on the amount of stormwater it can retain during a rain event, which, in turn, depends on its ability to release stored water between rain events. Green roof stormwater retention has been shown to vary with climate, storm size, vegetation type, and season. Green roof hydrological performance is usually assessed as the percent of rainfall captured over a defined period. Studies of runoff reduction by green roofs are still less common due to the complexity of capturing and measuring runoff and retention from the vegetation. While the reporting measures were not uniform, all studies reported lower runoff values than the total precipitation recorded. Older studies, such as a study by Villarreal et al. [20] reported retention rates of 21% up to 62% of precipitation, with values dependent on the total precipitation and the pre-existing conditions of the substrate prior to the rainfall. In another study [21], the annual average percent of precipitation stored by the green roof was 60.6%. The control surface, a gravel covered test plot, had average water retention of 27.2%. The lightest rainstorms, defined as 2mm or less, had the highest retention of precipitation with 96.2% reported for the green roof compared to 79.9% for the gravel roof. For precipitation greater than 6mm, the green roof had an average retention rate of 52.4% compared to the graveled roof that only retained 22.2% of the precipitation on average. The majority of studies report retention rates of approximately 30–35% averaged over the course of a year, month or the total number of events measured. The newer studies reported in Table 3, and others, show a seasonal trend in green roof hydrologic performance.

Table 2. Stormwater retention by season expressed in rainfall retained [%] from various studies

Study		**Uhl & Shciedt [22]**				**Stovien et al. [23]**	**Carson et al. [24]**		
Location		Muenster, Germany				Sheffield, UK	New York, USA		
Roofs		2	4	3	4	1	1	1	1
Depth [mm]		50	80	100	150	80	32	100	100
Mean % of Retention	Mar	57	58	62	72	76	43	61	42
	Apr								
	May								
	Jun	73	71	76	83	52	70	43	72
	Jul								
	Aug								
	Sep	57	58	62	72	35	22	40	78
	Oct								
	Nov								
	Dec	46	46	53	59	6	28	43	52
	Jan								
	Feb								

Table 3. Literature Review of Water Quality Results [25]

Study	**Location**	**Soil [mm]**	**Precipitat**	**Sulfate [mgL^{-1}]**	**Nitrogen [mgL^{-1}]**	**Ammoniu [m◦mgL^{-1}]**	**pH**
Bliss et al.	Pittsburg, PA	140	Actual	25.2–35.4	0	/	7.9–8
		Control		15.6–20.4	0.7–3.4	/	7.8–8.3
		Rain		8.4	1.2	/	6.4
Teemusk	Estonia	100	Actual	20–38	1.2–2.1	/	7.85–8.26
		Control		2–3	1.4–2.6	/	6.73–8.43
		Rain		<1	1.3	/	5.62
Berndtsson	Sweden	30	Simulated	/	1.7–2.3	0.01–0.025	/
		water		/	1.03	1.08	/

Like natural vegetated ecosystems, green ecosystems may be expected to exhibit seasonal fluctuations in runoff water chemistry due to variation in plant productivity, microbial activity, and other temperature or light-dependent processes. Although some green roof studies have noted variations in runoff water quality among rain events and across seasons, patterns or the processes underlying them are still partially unknown.

While some studies found lower levels of conductivity in green roof runoff following larger precipitation events, another found higher concentrations of total phosphorus and PO_4^{3-} and lower NO_3^- in green roof runoff during large events (Table 4.). There is a need for long–term observation, and also experimental studies on temperature and moisture dependence, so the seasonal patterns and key mechanisms that are controlling these patterns may become apparent.

3.4. Air pollution removal and air quality control

The process of pollution removal is depended on distinguishing features of various plant species, their habit, habitat, leaf physical parameters and weather conditions present in the areas. The tolerant species can be used for reducing the level of pollution and sensitive species as bio-indicators for monitoring ambient air quality. The mix of both types can be used for developing green belt in polluted areas.

Vegetation removes pollutants directly and indirectly. Plants take up gaseous pollutants through their stomata, intercept particulate matter with their leaves, and are capable of breaking down certain organic compounds such as poly-aromatic hydrocarbons in their plant tissues or in the soil. Air pollution, such as PM_{10} (which refers to particulate matter less than 10μm in diameter), is known to carry carcinogens small enough to bypass defenses in lung tissue and go deep into human lungs. Plants contribute to better air quality through their ability to catch particulate matter on rough leaf surfaces as the air passes over. A 1000m^2 green roofs can capture 160–220kg of dust per year, lowering the dust concentration in the atmosphere for about 25% [26]. Different abilities in dust capturing are mainly due to the difference in the surface properties of the plant leaves, canopy structure, and foliage density. Some plants can have dust capturing abilities 2–3 times higher than the others. The city of Los Angeles conducted the report and it was estimated that 2000m^2 of uncut grass on the green roof can remove up to 4000kg of particulate matter showing that one square meter of the green roof could offset the annual particulate matter emissions of one car.

If 20% of all industrial and commercial roof surfaces in Detroit convert to EGR 0.5% of that area's emissions, over 889 tons per year of NO_2, would be removed [27]. Assuming the NO_2 uptake rates by green roof plants were constant Corrie et al. [28] estimated the annual reduction of NO_2 by green roofs in Chicago and Detroit. Their study showed that covering 20% of the roof surface in Chicago resulted in the reduction of NO_2 between 806.48 and 2769.89 metric tons depending on the type of plants used.

Measuring the concentrations of acidic gaseous pollutants and particulate matters on a 4000m^2 roof in Singapore before and after the installation of a green roof Tan and Sia [29] found that after installation of the green roof the levels of particles and SO_2 in air above the roof were reduced by 6% and 37%, respectively. This field measurement proved that green roofs can reduce certain air pollutants but it is difficult to extrapolate their results to other places or to a larger scale.

Using the Urban Forest Effects (UFORE) dry deposition model developed by the USDA Forest Service the research in Chicago was conducted [30]. The model quantified levels and hourly reduction rates of NO_2, SO_2, CO_2, PM_{10} and ozone as well as their economic value. The total air pollution removal by 19.8ha of green roofs was 1675kg between August 2006 and July 2007. The 19.8ha of green roof consisted of 63% short grass and other low-growing plants, 14% large herbaceous plants, 11% trees and shrubs, and about 12% various structures and hard surfaces. Among the four air pollutants, the uptake of O_3 was the largest (52%) of the total uptake followed by NO_2 (27%), PM_{10} (14%), and SO_2 (7%). If all remaining roofs in Chicago were converted to Intensive Green Roofs, the direct removal of air pollutants could reach as high as 2046.89 metric tons.

Reductions in particulate matter, ozone, NO_x, and SO_x occur while plants are actively growing and in–leaf so evergreen conifers may provide a greater benefit than deciduous species because they retain their leaves year–round (Table 5.).

Table 5. Annual removal rate of air pollutants per canopy cover by different vegetation types in Chicago between August 2006 and July 2007 [30].

Vegetation Type	SO_2 [g/m^{2}yr]	NO_2 [g/m^{2}yr]	PM_{10}[g/m^{2}yr]	O_3[g/m^{2}yr]	Total [g/m^{2}yr]
Short grass	0.65	2.33	1.12	4.49	8.59
Tall herb. plants	0.83	2.94	1.52	5.81	11.10
Deciduous trees	1.01	3.57	2.16	7.17	13.91

Indirectly lowering surface temperatures by providing shade use of energy for air conditioning is less, due to reduced energy the emission of pollutants from power plants decreases. Calculations showed [31] that emissions from coal-fired power plants could be reduced by 350 tons of NO_x per day in Los Angeles by reducing the need for air conditioning. By changing the albedos of urban surfaces and through transpiration cooling vegetation also lowers the ambient air temperature, which in turn decreases photochemical reactions that form pollutants such as ozone in the atmosphere.

3.4.1 Carbon sequestration

When green coverage is less than 10%, the concentration of CO_2 in the air would be 40% higher than the one with 40% coverage rate, and when the coverage rate reached 50%, the concentration of CO_2 in the air can maintain the rate of 320 ppm. Carbon is a major component of plant structures and is naturally sequestered in plant tissues through photosynthesis and into the soil substrate via plant litter and root exudates. The carbon fixation and oxygen release capabilities of the green roof depends on the plant selection. Trees, bushes and shrubs are better in controlling the CO_2 concentration improving the environment and maintaining oxygen balance than the grass.

Getter et al. [32] quantified the carbon sequestered by four species of *Sedum* in 60mm substrate depth extensive green roof in Michigan over a period of two years. At the end of the study, above-ground plant material and root biomass stored an average of 168gCm^{-2} and 107gCm^{-2}, respectively, with differences among species from 64gCm^{-2} to 239gCm^{-2} for *S. acre* and *S. album*, respectively. Increasing substrate depth would not only provide a larger volume for carbon storage, it would also enable a larger plant selection that could include perennials and trees.

The research in Hong Kong, [33] in summer, showed that the extent of the green roof effectiveness depends on factors such as the ambient airflow condition, the green roof position, and the plant's condition. The CO_2 absorption rate of a plant in the daytime was much higher compared with the CO_2 emission rate at night providing the green roof ability to reduce the CO_2 concentration in the nearby region by nearly 2%.

3.4.2 Sterilization

Garden plants as the major species in urban greening have the important role in reducing the amount of environmental harmful pathogenic microorganisms and improving the urban environment's ecological value and adding social benefits. Plants can sterilize and inhibit the bacteria and other pathogenic microorganisms in their living environment to varying degrees. High green coverage rate helps to reduce bacterial content in the air. Some tree species produce essential oils called *phytoncides*, which when inhaled, improves mental well-being.

4. Guidelines, Codes, and Standards regarding Green Living Systems

In most EU countries the buildings were built before standards were introduced. Half of the residential stock was built before 1970. Two important parts in building life are proper installation and maintenance. The performance of buildings depends on a various factors such as climatic conditions, building envelope, the state of the installed systems, behavior characteristics of occupants and social conditions. Nearly 33% energy saving could be accomplished with deep retrofitting of the EU building stocks [34].

There is no national guideline, code or standard regarding Green Living Systems in Serbia. The first guideline concerning Green Living Systems appeared in 1982 as the Principles of Green Roofing published by the FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.) the German Research Society for Landscape Development and Landscape Design. Since 1992 Guideline for the Planning, Construction and Maintenance of Green Roofing has been remodeled many times as Green Roofing Guideline. It is recognized as the benchmark set of regulations for green roofing in Germany, linked into the DIN and EN standards and other regulatory publications and is therefore closely bound to the given building and construction standards. The FLL Green Roofing Guideline has been used as the groundwork for green living system documents around the world.

The GRO Green Roof Code was developed by English and European experts, including Livingroofs.org, GRO (Green Roof Organisation) members, The Green Roof Centre at the University of Sheffield, the Environment Agency, Homes and Communities Agency and Groundwork Sheffield. The GRO Code is significantly based on the German FLL Guidelines and adapted to suit the UK market intended to be used as a guide for green roof design, specification, installation, and maintenance.

The American Section of the International Association for Testing Materials (ASTM), the National Roofing Contractors Association (NRCA), the Whole Building Design Guide (WBDG) for federal building projects, the International Building Code (IBC), and the American National Standards Institute (ANSI) supported guidance for green living roofs. Green Roofs for Healthy Cities (GRHC) and Single Ply Roofing Industry (SPRI) in cooperation with ANSI have jointly developed a ANSI/SPRI RP-14 Wind Design Standard For Vegetative Roofing Systems and ANSI/SPRI VF-1 External Fire Design Standard for Vegetative Roofs. These design standards provides a method of designing wind uplift resistance of vegetative roofing systems utilizing adhered roofing membranes and method for designing external fire spread resistance. The intention was also to provide a minimum design and installation reference for designers and roofing professionals.

Factory Mutual Global Property Loss Prevention Data Sheets 1-35 – Green Roof Systems is one of the international guideline documents. This data sheet provides general instructions for Green Living Roof Systems reducing the chance of property loss due to fire, weather conditions, and failure of electrical or mechanical equipment.

Only few guidelines include information about the green living walls. A Concise Guide to Safe Practices for Vertical Greenery consists the inputs of the multiple agencies from Singapore. Growing Green Guide: A guide to green roofs, walls and facades in Melbourne and Victoria, Australia is a part of the project and is written for Melbourne and Victoria but much of information has national and international relevance. An introductory guide to designing and constructing green walls, UK Guide to Green Walls, was delivered by Urban Greening and New Build Landscapes aiming to provide environmental solutions to the UK Construction Industry. Nevertheless, we can point out that overall harmonized and international standardization is needed.

5. Conclusion

Foliage and soil layers protect the buildings from solar radiation, controls the temperature and the humidity of the indoor and outdoor environment. Plants absorb radiant energy to enhance biological photosynthesis preventing absorption of the radiation by the soil and the building structure. Occupants of buildings benefit by low outdoor and indoor temperature, more air flow and less air pollution. As a strategy to remove air pollutants, IGR with trees and shrubs are comparable to urban forests and play a much larger role in improving air quality than grasses or succulents that are often found on EGR. Implementation of green living systems in the building envelope, greening horizontal surfaces with intensive and extensive green roofs or using vegetation in vertical greening systems for façades, is a strategy that provides ecological, economic and social benefits.

There is a high potential for retrofit of buildings with green living systems in Serbia. This is caused by the huge energy losses annually due to lower insulation levels, if any at all, in old buildings. Green building envelope can improve the insulation properties of a building, hence reduce annual energy consumption and benefit from all of the above mentioned. Green living systems perform better when designed as ecosystems to promote biodiversity instead of monocultures. Climate specific modeling of environmental benefits, such as thermal buffering and mitigation of stormwater flows, is the most important step in future research to ensure their accurate representation in building sustainability indicators. Long–term evaluation of plant species, substrate formulations and irrigation regimes is required to support confidence in green living systems in Serbia. The national guideline, code or standard regarding Green Living Systems in Serbia should be produced or international recommendations implemented in existing Building Code.

Acknowledgment

This paper is part of the work within the National Program of Energy Efficiency, project number III42008, funded by the Government of Republic of Serbia.

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