

Greening the Grey – The Role of Green Walls in Regenerating and Revitalizing the Urban Realm

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Abstract—A conscious choice for switching to a more sustainable way of life has become the need of the hour. Design, construction and maintenance of buildings impact the environment and the natural resources in a significant way. Throughout the world, a large number of buildings are being built with many more yet to be constructed. The challenge will be to build them smart and efficient ones with a minimal energy, pollution, cost and judicious consumption of resources. Important issues that need to be addressed in a building include comfort, health and safety of people who live and work in them. Buildings and construction together account for thirty-six percent of global final energy use and thirty-nine percent of energy-related carbon-di-oxide emissions have continued to rise by around one percent per year since 2010, and more than four million deaths each year are attributable to illness from household air pollution (UNEP 2017). In the 21st century, people have begun to realize the importance of green architecture where new techniques and technologies have emerged in terms of green buildings such as green walls which are considered a new prospect for countering the phenomenon of urban heat island and energy conservation aspects. This paper will explore the concept, the types, the advantages and the techniques of the green wall as a part of the sustainable strategy for the urban environment. The green vertical surfaces can significantly contribute to the environmental, social and economic benefits of the built environment. The paper will further highlight why this emerging technology should be considered as a valuable part of the design process in addressing the emerging issues of climate change and energy crisis. The living wall could also function for urban farming, urban gardening or setup indoors to help alleviate sick building syndrome. Living walls are suitable for cities, as they allow efficient use of abundantly available vertical surface areas. They are also suitable in arid areas, as the circulating water on a vertical wall is less prone to evaporation than in horizontal green surfaces. Finally, the research will conclude with several recommendations for the use of living walls technique which suits the arid climate as a part of sustainable strategy for the urban environment.

Keywords - Bio Walls, Climatic Change, Green Vertical Surfaces.

Introduction

From the famous hanging gardens of Babylon, one of the ancient wonders of the world to the Caixa Forum Museum (Madrid), of the present day green roofs and walls have been an integral part of built form. The reasons for integrating were varied, ranging from increasing the insulation, improving the

aesthetics, better indoor and outdoor climate, reducing the greenhouse gases as well as enhancing the ecological values by creation of habitats for various birds and insects in the urban context.

Through the years, insensitive replacement of vegetated surfaces with paved and impervious surfaces in the urban areas have caused the temperature in the area to increase comparing to the surrounding rural area leading to the phenomena of Urban Heat Island. This is because the paved surfaces absorb, retain, and re-radiate more solar radiation than soft surfaces. As a result of this phenomena the ambient temperature in urban area can be as much/degrees Celsius warmer than the air in rural areas. The unprecedented rate of development over the past few decades have changed the surface profile of Delhi to a great extent. Many parts of the city including the CBD's have become denser, compact, and high resulting in increase in the hard paved surface area compared to the past years. With these rapid developments and change of surface profile, emerged the related environmental problems such as smog (resulting from temperature inversion), urban heat island, etc.

1. Urban Heat Island (UHI)

Urban Heat Island is characterized by significantly higher air temperature in densely built environment as compared to rural temperatures (Figure1). This is caused by the rapid urbanization and change of the land profile where more impervious surfaces such as asphalt, concrete and glass are found replacing the soft and green areas.

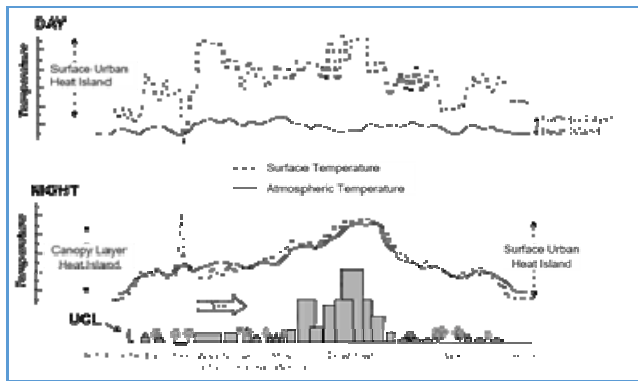


Figure 1: Diagram of an urban heat island profile

1.1 Causes of Urban Heat Island

The UHI effect has been explored worldwide and the cause of UHI can be summarized as below:

a) Canyon Geometry

Urban canyons, especially the deep ones, work as traps which decrease the loss of both short-wave and long wave radiation emitted from streets and building and eventually find their way into indoor space or radiate back to the surroundings after sunset.

b) Building Materials

During the daytime, more sensible heat can be stored in building materials, such as concrete, brick and asphalt, due to their higher thermal capacity. The stored heat will then be released back to the environment at night.

c) Greenhouse Effect

Long-wave radiation can easily be trapped inside the polluted urban atmosphere due to the greenhouse effect caused by the green-house gasses.

d) Anthropogenic Heat Source

Anthropogenic heat generated from industrial combustion, traffic, air-conditioners and so on can aggravate the UHI effect.

e) Evaporative Cooling Source

The UHI effect can be mitigated by evaporative cooling means, by increasing non-paved areas such as vegetation water body and so on, since more incident energy can be transformed into latent heat rather than sensible heat. Unfortunately, the lack of such evaporative cooling methods in cities, especially the loss of greenery, causes severe UHI effect.

f) Wind Pattern

Heat trapped inside urban canyons can be averted from source areas by turbulent transfer. However, such heat loss from within streets can be reduced where there is possible obstruction of wind flow by urban settings as shown in (Figure 2). In this case, ventilation in urban open space is of great importance.

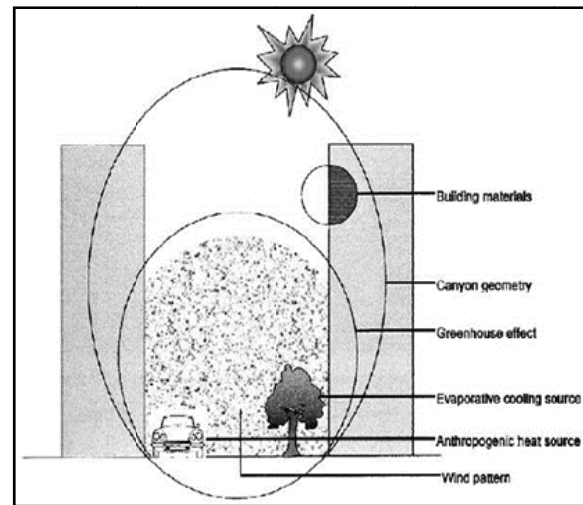


Figure 2: Diagram showing the most important factors that may influence the Severity of the UHI effect

2. Green Walls

Green walls or also known as vertical greens is actually introducing plants onto the building façade. Comparing to green roof, green walls can cover more exposed hard surfaces in the built environment where high rises are more predominant. According to Ken Yeang (1998), if a skyscraper has a plant ratio of one to seven, then the façade area is equivalent to almost three times the area. So, if the building is covered two thirds of the façade, this have contributed to doubling the extend of vegetation on site. So a skyscraper can become green, thus increasing the organic mass on the site.

2.1 Types of Green Walls

The green walls can be divided into three major types according to the species of the plants; types of growing media and construction method (Table 1).

Table 1: Comparison of three green walls methods

Type	Plants	Growing media	Construction type
Wall-climbing	Climbing plants	Soil on the ground or in planted box	Minimal supporting structure is needed
Hanging-down	Plants with long hanging-down stem	Soil in planted box on every storey	Planted boxes and supporting structure should be built at according storey
Module	Short plants	Lightweight panel of growing media (such as compressed peat moss)	Supporting structure for hanging or placing modules should be built on facades

2.1.1 Wall-climbing Green wall

The wall-climbing type is the very common and traditional green walls method (Figure 3). Although it is a time consuming process, climbing plants can cover the walls of building naturally. Sometimes they are grown upwards with the help of a trellis or other supporting systems.



Figure 3. Example of Wall-Climbing green wall at Trinity Business School, London

2.1.2 Hanging-down Green Wall

The hanging-down type is also another popular approach for green walls (see Figure 4). It can easily form a complete vertical green belt on a multi-storey building through planting at every storey compare to the wall-climbing type.



Figure 4. Example of Wall-Climbing green wall at Li Ka Shing University, Singapore

2.1.3 Module Green Wall

The module type is the latest concept compared to the previous two types. It requires more detailed design and planning considerations before a vertical system can come to place (as shown in Figure 5,6). It is also probably a more expensive green walls method.



Figure 5. Example of the module type green wall

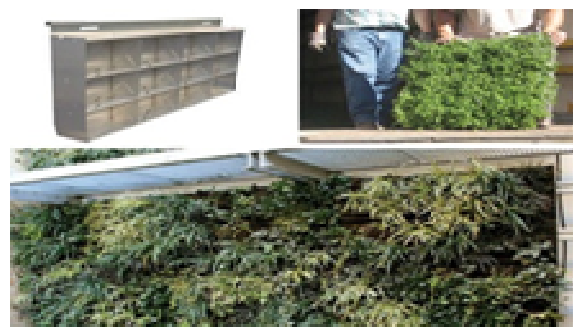


Figure 6. Example single unit of the module type green wall

2.2 Benefits of green walls in the built Environment

Plants in an urban environment provide innumerable benefits, in the form of environmental, social and aesthetic benefits. The benefits are actually inseparable and should be appreciated in the overall context of the built urban environment.

2.2.1 Environmental benefits

Plants offer cooling benefits in an urban environment through two mechanisms, direct shading and evaporative cooling (transpiration). The green walls provide shade to the building, the thermal insulation is directly proportional on the density of the plants in the green walls. Hence, it not only shades the building, but also reduces the ambient temperature in the vicinity of the building affecting the urban environment.

Plants and trees, have been widely believed to be effective in reducing both gaseous and particulate pollutants from the atmosphere in the urban environment. They can improve the air quality by filtering out airborne particles in their leaves and branches as well as by absorbing gaseous pollutants through photosynthesis.

By using green walls, limited spaces or lack of land is no longer a problem, as it covers the building façade, thus the air quality in the urban area with high rise and skyscrapers can also be improved.

Traditionally storm water in the urban area runs off impervious surfaces and finds its way to drainage-pipe systems and finally to an adjacent water body. Flooding occurs when the drainage is incapable of handling and distributing the storm water from the land. A degraded aquatic ecosystem is usually associated with the discharge of the storm water. Hence Green wall acts as a mulching technique as it covers the impervious surface of the building with plants and soil or planting medium and helps in retaining water to control the water runoff from the roofs.

Urban green area and vegetation around the buildings are being viewed as an alternative habitat for urban plants and native animals and birds. The presence of flora and fauna enrich the ecological quality of the environment as well as provide additional social and physical benefits to humans. Apart from that, plants also release oxygen to the atmosphere through photosynthesis and reduces carbon dioxide thus helping in carbon sequestration.

The role of plants in filtering the impurities in the water before it enters a groundwater aquifer is also well known. Impurities, such as nitrogen and phosphorus, will bond together with some types of soil. Plants can reduce the amount of these impurities in the soil by taking up nitrogen and phosphorus to be used in the plant growth.

Last but not the least, plants can be used as sound barrier as they can reduce and muffle noise which is generated from various sources especially in an urban environment. In the case of green walls, plants in the green walls will help in absorbing the sound. Thus, helping in the mitigation of the noise pollution in urban areas.

2.2.2 Economics benefits

Economic benefits are associated with the environmental benefits in case of green walls. The ability of the vegetative surfaces to retain storm water and water runoff from the roofs can help in reducing the extent of the storm water drainage infrastructure and control urban flooding.

Plants if introduced carefully around buildings can improve the life of the surface materials by reducing the weather effect. The use of green walls can reduce the climatic and thermal stress on building façades thus, prolonging the life of buildings and reducing the costs in maintenance.

Energy saving is another significant economic contribution brought by careful intervention of greenery in the urban environment. Studies have proved that the energy used for cooling in a building can be vastly reduced by the introduction of greenery.

Landscaping can also add value to the property. It is often used to improve the aesthetic value of the urban area. Vegetation provides visual contrast and relief from the highly built-up city environment.

Apart from that, natural landscape provides elements of natural scale and visual beauty as well as seasonal indicator to buildings and streets. In addition, the 'softness' of the greenery compared to the hardness of concrete can also provide visual relief to plain walls. Ugly buildings can be hidden by the green walls and vegetation.

2.2.4 Social Benefits

Plants can fulfill various functions. According to Givoni (1991), plants provide places for playing, sports and recreation, meeting establishing social contacts, isolation and escape from urban life, aesthetic enjoyment, viewing buildings from a distance and so on. It has been proved that visual and physical contacts with plants can result in direct health benefits. Plants can generate restorative effects leading to decreased stress; improve patient recovery rate and higher resistance to illness.

3. Use of Green as Mitigation Measures for UHI

Plants or greenery undoubtedly play an important part in improving our climate, regardless of meso or microclimate. Plants provide shade and protection from the sun and wind, decrease the air temperature, increase humidity, and reduce the surface temperature in the built environment. However, the ability to influence the climate is much decided by the density and the plant species. For example, an open lawn or meadow can do little to the overall climate as compared to a dense forest. However, the density and the plant species does play an important role in influencing the micro-climate of the place.

In general, plants can influence the micro-climate generally through shading, wind shielding, evapo-transpiration and photosynthesis processes. Most of the solar radiation are intercepted and trapped by the dense foliage of the plants, except for a very small portion transformed into chemical energy through photosynthesis. The absorbed solar radiations are then modified to latent heat which converts water from liquid to gas, resulting in low leaf temperature, lower surrounding air temperature and higher humidity through the process of evapo-transpiration. In other words, the UHI can be alleviated through these mechanisms.

4. Case Studies

The practice of incorporating plants into buildings have become a popular trend recently, as the awareness for climate change and sustainability has caught the fancy of the developing nations and especially the Building Councils of the world at large. The main focus of this concept is to make buildings lively and to incorporate nature into the built-form. This concept also considers local climate for its lighting and ventilation according with the use plants for cooling and refreshing the indoor environment and help reduce the heat gain from the outdoor, thus limit the use of mechanical HVAC systems and resulting less use of energy. The following cases are considered here to study the recent typology of practices

according with their views and concepts including indoor and outdoor planting.

4.1 Chilean Consortia Building, Santiago, Chile: Case Study of Outdoor Planting

Architect: Henry Browne - Borja Huidobro

Location: Las Condes. Santiago, Chile Owner: National Trust Insurance - Life

Built Area: 26,720 m² Surface: 3781 m²

Architects Henry Browne and Borja Huidobro were instrumental in building the National Insurance building in Las Condes, Santiago, Chile. The building has various eco-friendly features that has made it a sustainable building. One of the features is its interior and exterior thermo panels vegetation that absorbs the radiation of the sun. Another great green feature it has is the front wall that turns into a vegetable garden of around 3000 square meters vertical, wherein the plants changes into different looks over the years depending on the season as shown in figure 7.

The facades were developed with particular care. The western orientation of the building is protected by the double facade construction that allows vegetation to grow on a system separate from the building. The vegetated facade makes up about 3,000 square meters. From the interior, it creates a lush barrier, shading its inhabitants from the beating sun and inside creating an atmosphere more like living inside in a secret garden as shown in figure 8. When the plants are not a luscious green, they turn colors of bright reds and yellows in the fall. While MFO Park using mostly cable system for the plants to grow on, there is a second track halfway up the structure that is like a large planter that runs the length and provides a second level of vegetation. The track also has an area for maintenance workers to walk and take care of the plants and lighting as shown in figure 9 [12].

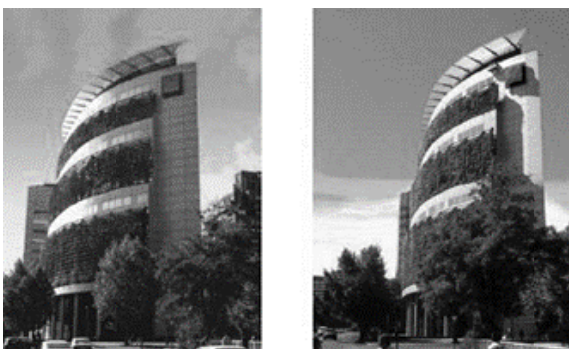


Figure 7. Chilean Consortia Building, Santiago, Chile

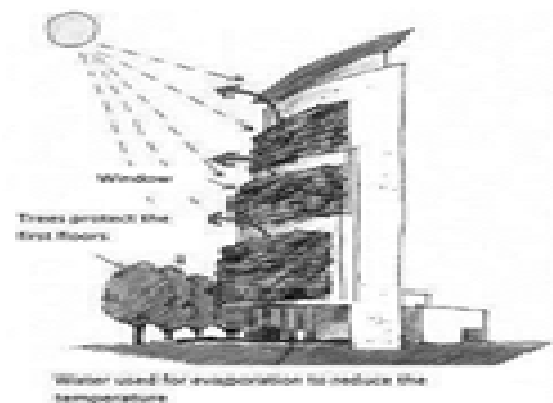


Figure 8. Concept drawing for the green façade

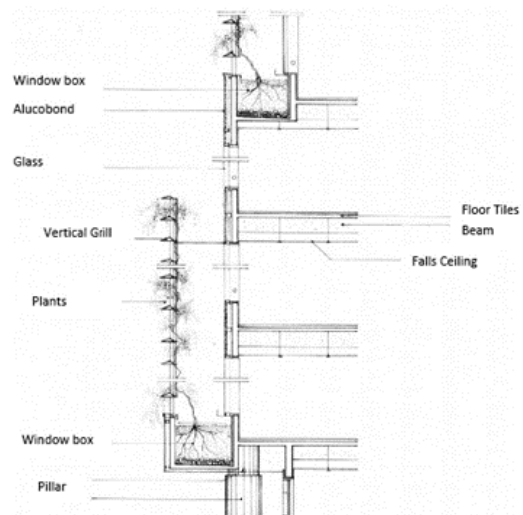


Figure 9. Detail Vertical Section.

4.2 Tokyo Nara Tower, Tokyo : Case Study of Outdoor Planting

This 126 stories skyscraper will be sited in a cold climatic zone and deciduous forest type vegetation zone. This is a proposal for an ecologically responsive hyper tower. The tower is an extension of the park in sky idea. The design can be summarized as the 'hollow of the vertical rotating spiral' using a system of shifting vertical landscaping terraces.

The verdant foliage protects the building by way of shading in the summer. By photosynthesis it creates a healthier microclimate at the façade. The fringing of the floors and the atrial spaces further reduces the impact of high wind speeds on the built structure. The ratio of the mass of planting relative to the built structure is favorably comparable, thereby ensuring that the bio system components are balanced and acting symbiotically with the structure's mechanical and electrical systems as an artificial ecosystem as shown in figure 10.

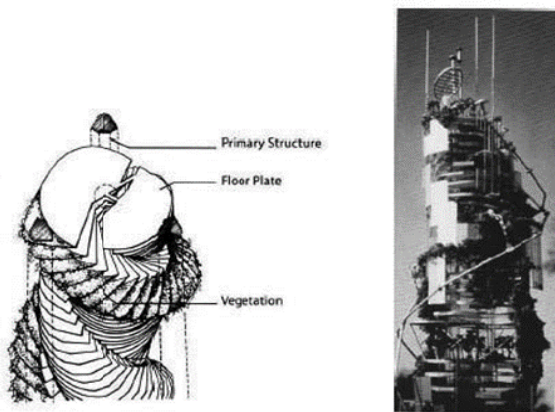


Figure 10. Tokyo Nara Tower, Tokyo. Plant integration with the spiral structure of the tower.

The greenery in the built form, act as its lungs, like a breathing life into the floors, above and below, via the internal atrial voids [13]. The green lungs also refreshing the environment, improving the air quality and provide:

1. Vegetation on façade for sun-shading and microclimatic control.
2. Decorative landscaping for interior aesthetics.
3. Vegetation pockets located at public areas as natural air fresheners.

4.3 The Genzyme Center: Case Study of Indoor Planting

The Genzyme Center is an example of a company doing the right things and this building was chosen as an AIA Top Ten Green Project for 2004. The goal of the design was to develop a building from the inside out, from the individual working environment to the overall complex structure of the building [14]. There are eighteen gardens contributed to the green building concept. The building act as a living organism that would provide a connection to the outside through a visual connection with the outside, to look outside at the green and to bring that green into the building through the gardens and it was a high level of commitment to include the interior plants because it was the right thing to do for a green building as shown in figure 11.



Figure 11. Indoor Planting in Genzyme Center

Interior planting in this building has mostly been met with a positive response. The air quality in the buildings is excellent, the shading and air-conditioning functions and also the aesthetic effect indoors is viewed positively. In administrative buildings, the number of staff off sick has decreased \pm the individuality of the workplace plays a role here.

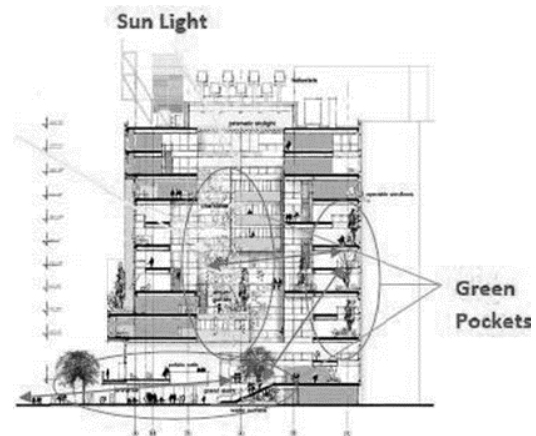


Figure 11. Indoor Planting in Genzyme Center (Conceptual Sketch)

Discussions

Sustainability and green buildings are the latest buzzwords among the building clients and developers. The recent launch of the new United Kingdom Green Building Council (UKGBC) is likely to increase the awareness. The Green Building movement is becoming ever more important as architects and developers strive to find ways of constructing and managing buildings in a sustainable and environmentally-friendly fashion.

The paper presented many ways to incorporate plants into buildings, as in roof, vertical walls, bio filters and in indoor potting plants. All these provisions have their own typology, technology of installation and maintenance as well as some drawbacks which need more extensive research to overcome.

There are options for the green wall design. It could be the climbing plants or the modular panels. For the skyscraper design both the options could be used together. For the lower levels the climbing plants, while rooted on the ground could be used in a designed manner, the hanging plants could be planted on the roof top that will cover the wall on the top most level, while the modular panels could be used for the rest of middle floors. It could save time and money for the maintenance as those types of plants require little or no maintenance than the green panels.

Conclusion

Extending the plants or greenery onto the building façade has shown potential in improving air quality and reducing surface temperature in the built environment. Plants certainly help to

promote thermal comfort as they cool down the building façade and the surrounding by transpiration. This can be perceived from the study as the outdoor environment remained at the thermal comfort range, where Plants give balance between temperature and relative humidity thus help in modifying the outdoor thermal comfort. Therefore, the capability of the green walls in improving ambient air and temperature even though they do not act as a shading device has been identified.

Even though the basic mechanism for CO₂ consumption is through photosynthesis, it is important to consider that relying on the green wall alone will provide a better environmental quality. Nevertheless, it is a part of the method in contributing towards enhanced outdoor environment and maintaining the ecological systems in the urban area.

Recommendations

Ground coverage, green walls, sky courts, indoor plants and roof top gardens works together to make buildings μ *UHHQ¶. 7KH vertical landscaping is one variation on the creation of roof top gardening; another variation is the green wall, which encapsulates the principle of a single element with multiple functions [15]. The breathing wall with vegetated façade according with the sky courts tends to focus to develop the building as an ecologically complex and stable plant, microbial and human community, that helps to improve the air quality in an interface between natural processes and the built structures environmental system. The whole system works for the social, ecological and environmental benefits. If this system multiplies and implemented to all the skyscrapers in an urban area the beneficiary will be all the species including the humans. The results will be the noticeable decrease in urban heat island, rapid reduction of energy consumption and refreshing air for a healthy environment.

Factors for Successful Green Facades

Design, installation and maintenance considerations for green facades and living walls will vary by system type selected and the conditions of the built and natural environment.

Green facade projects require that the designers, installers, manufacturers and maintenance staff take the following into careful consideration:

- Attachment to building envelope ± how the system will be secured to the building or freestanding structure.
- Calculation of structural loads for larger systems, resulting from loads such as snow, plants, and wind.
- Plant selection for wind and light exposure, hardiness zones, and amenity context.
- Realistic expectations related to plant aesthetics and growth and some systems require 3 to 5 years to become fully established.

- Plant maintenance and/or long term maintenance plan to secure the health of these living systems, including proper soil and irrigation considerations.

- Check with manufacturers who may have registered or specially trained installers that will be able to complete the project successfully.

- Appropriate plant selection for the geographic region, correct plant spacing for desired coverage, and release from the temporary support structure used by the nursery.

Educational Benefit of green roof and green wall: A socially viable issue

Green Roofs and Walls are the perfect tools to teach about the environment. The next generation needs to learn about the environmental concerns of today and how we addressing them. Problems like the Heat Island Effect, Global Warming, CO₂ reduction in cities are all addressed by Green Roofs and Walls. Just a few of the topics that Green Roofs and Walls may be used for in education are:

- ‡ Ecological Observation
- ‡ Growing Plants and Vegetables
- ‡ Identifying the Protection of the buildings

Thus the educational opportunities are endless.

References

- [1] Thompson J.W, Sorvig K.(2008). Sustainable Landscape Construction; A Guide to Green Building Outdoor. (2nd Edition) United State of America: Island Press.
- [2] Wong N.H, Chen Y. (2008). Tropical Urban Heat Islands, Climate, buildings and greenery. New York: Taylor and Francis Group.
- [3] Wilmers, F. (1990/91). Effects of vegetation on urban climate and buildings. Energy and Buildings, 15-16, 507-514.
- [4] Jonathan, A. (2003) Vegetation ± Climate Interaction: How Vegetation Makes the Global Environment. New York: Springer.
- [5] Susan Ioh, 2008, "Living walls – away to built the green environment, available online a www.environmentdesignguide.com.au/media/TEC26.pdf
- [6] Dwyer, J. F., Schroeder, H. W. and Gobster, P. H. (1994). The deep significance of urban trees and forests. In R. H. Platt, R. A. Rowntree and P. C. Muick (eds), The Ecological City: Preserving and Restoring Urban Biodiversity (pp 137- 150). Amherst: University of Massachusetts Press.
- [7] Dunnet, N, Kingsbury, N, (2004) Planting Green Roofs and Living Walls. London The London Ecology Unit.

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- [8] Johnston, J. and Newton, J. (1996). *Building Green: A Guide for Using Plants on Roofs, Walls and Pavements*. London: The London Ecology Unit.
- [9] Wilmers, Facer. (1997). Effects of vegetation on urban climate and buildings. *Energy and Buildings*, 15-16, 507-514.
- [10] Wilhelm, K. (2008). The Urban Climate: Basic and Applied Aspects. In: J.M Marzluff et al., *Urban Ecology*. New York: Springer.
- [11] Pastorelli, Giuliano, (2009), Plataforma Arquitectura, Web Article, Posted in: Architecture Office, Landscaping, from <http://www.plataformaarquitectura.cl/2009/01/21/edificio-consorcio-sede-santiago-enriquebrowne-borja-huidobro>.
- [12] Town, Lisa, (2009), Sustainable Cities Collective, Web Publication. Categories: Alternative Energy, Design & Architecture. From <http://sustainablecitiescollective.com/Home/17628>.
- [13] Yeang, K. (2007), *Eco Skyscraper*, Australia, Image Publishing, ISBN 9781864702682.
- [14] Fjeld, T., et al., (1998), "Effect of Indoor Foliage Plants on Health and Discomfort Symptoms Among Office Workers," *Indoors + Built Environment*, 1998, 7:204-206. (Norway). <http://greenplantsforgreenbuildings.org/pdf/Authenticallly%20Green%20Interiors%20Paper%20copy.pdf>
- [15] Yeang, ken, (2006), *Eco-design: A Manual for Ecological Design*, Wiley Academy, Great Britain. ISBN 0-470- 852917.
- [16] *Green Roofs for Healthy Cities: Introduction to Green Walls ±* www.greenroofs.org
- [17] Vazhacharickal PJ and Buerkert A (2011). Sustainable cities: an overview of the urban and peri-urban agricultural production in Mumbai Metropolitan Region (MMR).