

# An Evaluation of Green roofing in Buildings

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**Abstract-** As a result of urbanization and industrialization, the world started facing some environmental complications such as urban heat island which can raise air temperature to about 2-5% in a city or more, noise and air pollution, storm water run-off, ultra violet radiation etc. But the introduction of green roof in our modern buildings after a series of researches in late 20<sup>th</sup> century especially in Germany and other European countries tend to minimize these environmental complications to a reasonable level. Therefore this paper is going to discuss about green roofing in buildings with reference to its history, types, application, and its benefits on the environment. Furthermore, some case studies of both intensive and extensive green roof were selected randomly from some buildings and which were compared, discussed, conclusion and recommendations were drawn from the case studies.

**Index Terms-** Green roof, Sedum species, Perennials plants, Sustainability, Economic and environmental benefits, Urbanization, Industrialization, Thermal comfort, Urban centers, Energy efficient.

## I. INTRODUCTION

Green roof has been in existence for over 3000 years, the earliest green roofs were seen to be as form of a turf roof. The turf roof contains growth of grasses and plants roots and this kind of roof is still in existence in Norway and Iceland. In warm climatic region green roof was first identified as roof garden which was seen in the ruins of Pompeii after the volcanic eruption of Vesuvius Mountain in AD 79. Green roof was also seen in the famous Hanging Garden of Babylon which was constructed around 500 B.C. During Middle Ages green roof was also found in Guinigi Tower, Lucca, Italy (Stater, 2008).



Figure1: Turf Roof (Magnusson 1987)



Figure2: Farm house with Turf Roof (Nancy Marie Brown 2001)

Modern green roof emanated from Germany and Switzerland in 1960s after a lot of researches were taken place about terraced green roof technologies. A German researcher Reinhard Bornkamm published his works in 1961 on green roof which really helped on understanding green roof more. In 1961 Geno Haus was also built and it was functional until 1990 (Metropolis Magazine). In 1970 other important researches were also taken place on green roof especially on its components like, root repelling agents, water proofing membrane growing media, drainage etc. Some of these researchers were Gerda Gollwitzer and Werner Wirsing. In 1980 green roof market gained so much acceptance with annual growth of 15% to 20%. In 1989 about 1 million square meters of green roof were used in Germany and by 1996 that number rose to 10 million square meters. This success was achieved as a result of help and encouragement from the German Government which it contributes 35 to 40 Deutch Marks per square meter of roof. Such kind of gesture was copied

in other European countries with some of their large cities and urban areas incorporating roof and vertical greening in their planning regulations and these gave birth to a new green roof industry for supplying plants and materials, installers and maintenance crew and green roof professionals. In countries like Germany, France, Austria, Norway, Switzerland and other European countries green roofs have been accepted widely in their construction industries and urban landscape (Peck et al, 1991).

Countries like Germany, Switzerland and Scandinavia have the highest contribution on Europe's earlier green roof researches and they were not written in English (Dvorak, 2010, Koehler, 2007, Mentens et al., 2006). Furthermore, Dvorak (2010) stated that the wide experience about green roof led to improvement of guiding principle based on academic research, product improvement and field research. These guiding principles were developed by research group called FLL meaning

Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau in Deutsch while English meaning the German Landscape Research, Development and Construction Society and are used for green roof design, conditions, maintenance and analysis. The FLL started developing the guiding principles in 1975 and were published in Deutsch in 1982 while in English in 2002.

Green roof in our present world is not only common in Germany which about 14% of their flat roofs are green roofs but it's also common in United State of America Before the urbanization and other human advancements vegetation and soil were used to control storm water and solar energy efficiently but presently green roofs serves as one of the effective methods of controlling storm water and solar energy (Getter, 2006).

United State of America also developed their own green roof guiding principles which are different from the FLL in Germany, and the guiding principles were developed by the Association of Standards and Testing Materials (ASTM) to serve as a guide green roof plant selection, maintenance, and requirement for structural load and green roof layers (Dvorak, 2010).

Recently other researches are ongoing in North America about green roof which the findings will also be added to their green roof standards (Magill et al., 2011).

## II. DEFINITION OF SOME TERMS

### Green Roof

Green roof can be defined as a roof that contains plant or vegetation and it may be fully or partially covered on the roof and it's an addition on a normal concrete decked roof (Dvorak, 2010). Green roof has several layers The top layer is the vegetation stratum, followed by growing medium or soil layer, irrigation layer, filter fabric layer, drainage layer, waterproofing membrane layer, and then the roof deck (Dunnet & Kinngsbury, 2004, Ouldoukhite et al, 2011).

Green roofs cost more than the normal traditional roof but it has its own advantages and benefits on the long run which will counter the initial cost of installation (Dunnet & Kingsbury, 2004).

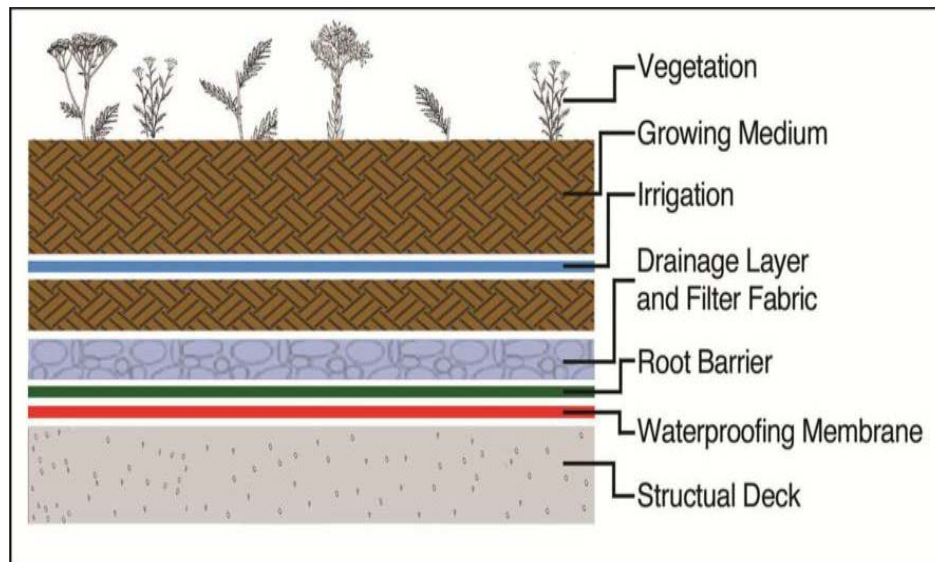


Figure3: Layers of Green roof (www.greenroofs.org)

Green roof has two modes of arranging the layers and these are: The built-up system are arranged in layers and they are been put together layer by layer and this can be seen in figure 3 above. The Modular system is quite different from the built-up system

where as in the modular system, the growing media or soil, filter cloth, drainage layer are transportable or arranged around the roof like a floor-covering or grid pattern. This can be seen in figure 4 below



Figure 4: Modular method arranging green roof ([www.greenroofs.org](http://www.greenroofs.org))

### Types of Green Roof

According to Mentenser et al. (2006) depth of green roof substrate layer defines green roof into two types which are the intensive and extensive green roof.

#### Intensive Green Roof

Intensive green roof is the type of green roof that contains different types of vegetation starting from grasses, shrubs to small trees. It's often roof garden and it may also include walkways, benches, tables, and fountain on the roof. The intensive green roof has a depth greater than 150mm. This type of green roof has a heavy weight and required high maintenance (Magill et al., 2011). The slope of an extensive green roof is less

than  $10^0$  (Kolb and Schwarz, 1999, Krupka, 1992) Intensive green roof can weigh from  $171 - 391\text{kg/m}^2$  (Breuning, 2015)

#### Extensive Green Roof

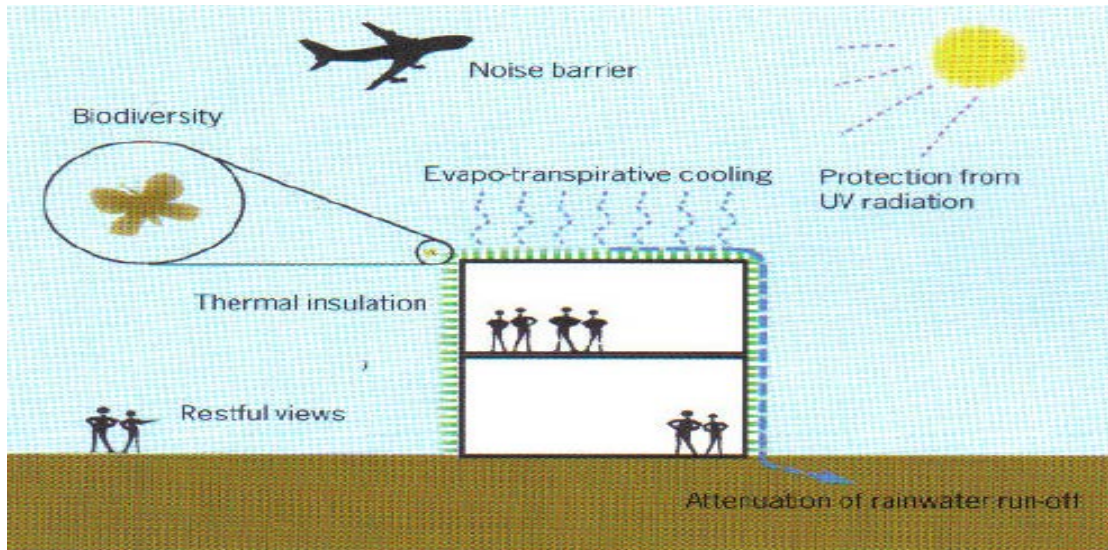
The extensive green roof is simpler compare to intensive green roof because it's lightweight and requires low-maintenance and drought resistant plants usually sedum species are used. It also has thickness of less 150 mm. According to Breuning (2015) extensive green roof can weigh from  $73\text{kg/m}^2$  to  $122\text{kg/m}^2$ . Looking at extensive green roof from sustainable point of view it's considered to be more important because it has low weight and can be used in more rooftops compare to the intensive type (Benvenuti, 2010). When elements of both extensive and intensive green roof are found in green roof it's considered to be semi intensive green roof (Ampim, 2010).



Fig 5: Extensive green roof (Breuning, 2015)

### Benefits of Green Roof

Green roof is known to be used widely in our world today because of its lot of benefits to our environment and some of them can be illustrated in the picture below



**Figure 6: Benefits of Green roof (Stater, 2008)**

According to Stater (2008) some of the benefits of green roof can be urban heat island control in the urban centers, provides thermal insulation to the building, provides thermal comfort to the buildings both in winter and summer seasons, serves as a biodiversity for plants and animal, serves as noise and air pollution barrier through absorption of noise pollution from heavy machineries or aero plane in cities and it also absorbs toxic

air been emitted to the environment, provides an aesthetically pleasing environment, protection from ultra violet radiation being emitted by the sun, improving the lifespan of the roof and buildings, control of storm water run-off. Vanvert et al, (2005) also stated that green roof can reduce storm water run-off by 50%-60% and sometimes it can fully stop storm water run-off.

**Case study 1(Empire State Building 30<sup>th</sup> Floor West)**



**a**



**b**

**Figure 7: a showing sedum species, b showing layers of the green roof. (www.greenroofs.com)**

The 30<sup>th</sup> Floor West Green Roof is located in Empire state building, New York City, USA. It's an extensive green roof of 112 square metre, a slope of 1° and its light in weight. It was designed by Xero Floor America, LLC and it was built in 2013. The plants grown are sedum species of succulent leaves together with ferns and moss species. The plants were grown on a mat off

the site and were brought to the site for installation. This green roof is only accessible for maintenance.

Furthermore the Empire State building has other green roofs in the 21<sup>st</sup> floor and 25<sup>th</sup> floor with sizes of 321 square metre and 93 square metre respectively. The use of green roofs in Empire State Building helped in reducing its energy consumption and as a result of that the building is acknowledged with Energy

Star rating of 80 by Energy Star Program and it's also considered as one of the top 20% energy efficient buildings in the Program. Also the Empire State building is also been acknowledged with LEED-ED Gold recognition by USA Green Building Council.

### Case Study 2 (Hewlett Packard Building 4A Green Roof)



Figure 8: a and b, showing green roof plants and paving ([www.greenroofs.com](http://www.greenroofs.com))

The Hewlett Packard Building 4A green Roof is located at Palo alto California, USA and it was designed by Royston Hanamoto, Alley and Abey. It was built in 2011, and it has a size of 1747 square metre and a slope of 1°. The roof consist of green area and paved walkways. The green area consist of sedum plant species mixed with some perennial plants and three combinations were used. Sun & Shade combined with *Fragaria chiloensis* and

*Stipa tenuissima*, *Color Max* combined with *Escholzia californica* *Maritima* and *Achillea millefolium* *Paprika*, All seasons combined with *Thymus serpyllum* *Coccineum*. This green roof is private and accessible.

### Case Study 3 (Headquarter Honda Green Roof)



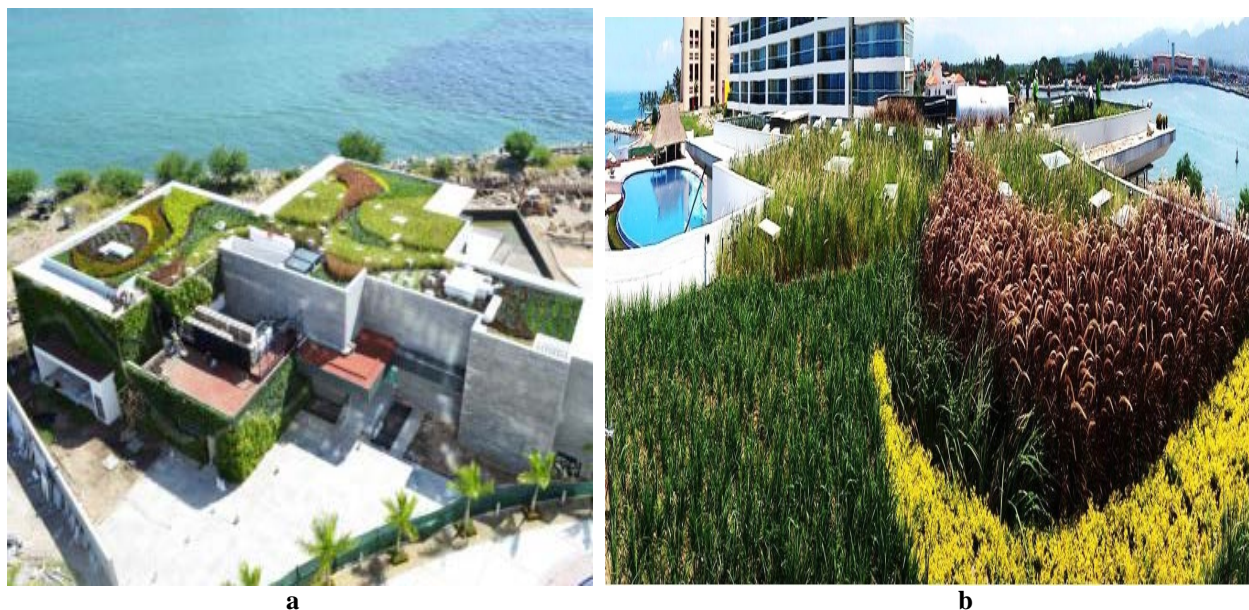
Figure 9: a showing top green roof and PV panels, b showing sedum and perennial plants ([www.greenroofs.com](http://www.greenroofs.com))

The Headquarter Honda is located in Florida, USA and it's a commercial building. The building tend to be highly sustainable because it incorporate green roof and PV solar Panels. The green roof was completed in 2010 and it has 557 square meter of extensive green roof and a slope of 1.5°. It also has solar system of 126kw. As a result of harsh weather in Florida during winter, the vegetation were nursed offsite and were installed in mid-March. This green roof was laid in a modular system of arrangement with 488 square metre of vegetation like Muhly grass, Gaillardia, Sunshine Mimosa,

Black-eyed Susan, Purple love grass, and Frogs fruit. It also contains 130 square meter of Pavers. Irrigation of the green roof is made through drip irrigation system and is sourced from a massive underground Cistern.

Integration of Solar PV panels and Green roof was used in the Headquarter Honda in order to maximize the advantages that comes with eco-friendly materials and this building is said to be considered as a LEED Platinum project.

**Case Study (Casa Vallarta Green Roof)**



**Figure 10: a showing top view of green wall and green roof, showing green roof plants ([www.greenroofs.com](http://www.greenroofs.com))**

Casa Vallarta Green Roof is a green roof on top of single family residential building. The building is located near Pacific Ocean in Puerto Vallarta Jalisco, Mexico. The building is highly eco-friendly thus it contains both green roof and green wall. The green roof and green wall was designed by Cynthia Villalba and completed in 2012. It's an intensive type of green roof with size of about 711 square metre. It also has a slope of 1°. The green wall is situated at different levels on the north-east façade and it has a size of 287 square meter.

In the green roof tall trees and grasses were planted and the designer took the advantage of the site being close to an ocean so tried to have some kind of movement reflecting on his design through the use of curves in the landscape tracing pattern. The designer also tried to add beauty to the green roof by use of harmonic colors and these can all be seen in figure 10 above. More than 19619 plants ranging from grasses, agaves and perennials were planted on the green roof while short grasses and ferns were planted on the green wall.

The storm water and irrigated water on this green are being captured and recycled and used for further irrigation their by saving cost. The incorporation of green roof and green wall in this building tend to provide high insulation from heat there by reducing the cost of air conditioning.

III. DISCUSSION

	Empire State Building 30 <sup>th</sup> Floor West Green Roof	Hewlett Packard Building 4A Green Roof	Headquarter Honda Green Roof	Casa Vallarta Green roof
Location	Manhattans New York, USA	California USA	Clermont Florida, USA	Puerto Vallarta Jalisco, Mexico
Plants	Sedum species	Sedum species and perennials	Grasses and Sedum species and perennials	grasses, agaves, and perennials
Green roof type	Extensive	Extensive	Extensive	Intensive
Size	112 square metre	1747 square metre	557 square metre	711 square metre
Climatic Region	Humid Continental	Mediterranean Like	Subtropical	Subtropical
Slope	1%	1%	1.5%	1%

Other Sustainable Materials			Solar PV panels	Green wall	a roof cover to buildings due of lack of sophisticated building materials, but as cities grow and man advanced technologically through industrialization and urbanization, and these industrialization and urbanization tend to affect the natural environments with side effects which causes discomfort to man and other living organisms in the world, therefore the need for sustainable environment arose which green roof tend to be the one of the key solutions which will help to reduce these side effect to a reasonable percentages.
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In Case Study 1 (Empire State Building 30<sup>th</sup> Floor West Green Roof) the green roof is simpler which was characterized by the use of suitable Sedum species mainly succulents there by defining the green roof as an extensive type. Those Succulent sedum species were used in this case study because they are adaptable to the weather in New York, they are drought tolerant and store water in their leaves there by making it easy to maintain. This green roof is only accessible when it comes maintenance therefore its main purpose is to provide environmental benefits and that's also a reason why Extensive green roof was chosen. The Green roof helped in reducing the energy consumption of the building which helped the building to gain an award for Sustainable buildings.

In Case study 2 (Hewlett Packard Building 4A Green Roof) the green roof is an extensive green roof but it can also be refer to semi-extensive because it contains both features of extensive and intensive green roof. The green roof contain sedum species and perennials, and it's a bit complex than in case study 1 (Empire State Building 30<sup>th</sup>) because three separate mixtures sedum species and perennials were used. Thus the present of perennials in this case study makes maintenance very frequent because they require it adequately for them to survive unlike sedum plants. The use of these plants in this case study made it possible for the green roof to serve as roof garden and also to provide other benefits like cost efficiency in the long run, energy saving, thermal comfort in both winter and summer etc.

Case study 3 (Headquarter Honda Green Roof) is also an extensive green roof but it can also be called a semi extensive green roof because it also contains perennial plants apart from sedum species. It's similar to case study 2 (Hewlett Packard Building 4A Green Roof) but here it also has a PV solar panels at the other part of the roof. The solar panels serves as an alternative source of electricity to the building and it provides cost efficiency to the building at the long run. This green roof also requires adequate maintenance because of the use of perennial plants. The selection of the sedum species and perennials was made in order to maximize both the environmental and economic benefits that comes with green roofing and also to serve as a roof garden.

Case study 4 (Casa Vallarta Green roof) is an intensive green roof, it contains grasses, agaves and perennials. It's more complex than the remaining case studies because the selection of plants. Here the use of the perennials and agaves added another purpose to the green roof other than to mitigate some urban centers problems but also it can serve as a garden where people can go and enjoy the natural environment. In this case study also there are green walls on some facades of the buildings which can provide thermal insulation to the building. High maintenance and care is required here because of high density and different varieties of plants.

#### IV. CONCLUSION AND RECOMMENDATIONS

In the past use of green roof was not emphasized because things were simpler. It was mostly used for aesthetics, or serves

It's been seen that green roof can be mainly of two types which are intensive and extensive and when the features of both are combined together in one roof it's called semi extensive. Both the intensive and extensive green roof can be used to reduce the side effects caused by urbanization and industrialization of urban areas to a reasonable percentage. The intensive green roof can also serves as a roof garden but it requires high maintenance because of wide range of plants used in it, but it has been seen in this study that most of the times people prefer extensive green roof in their buildings to achieve sustainable environment and other benefits like urban heat island control, storm water run-off control, energy efficiency etc., because it does not require much maintenance and irrigation as a result of the use of drought tolerant and succulents sedum species.

It's also been seen that green roof installation needs to be done by professionals because a lot of considerations needs to be taken place for it to survive and thrive, therefore it's advisable to invite professionals when considering going green in your roof. Due to the fact that our present world is experiencing a threat of climate changes more awareness through seminars and conference should be made to the public about green roof in other to gain more acceptance.

Urban cities can take the advantage of wasted spaces in the normal flats roofs of the buildings by making it green roof in order to enhance a more sustainable environments.

Also green roof is more popular in western world, other parts of the world like Africa should try to emulate the western world in using green roofs in their buildings and this will be achieved through series of researches and government interventions.

Researches should be carried out more on native plants around the world so that the use of green roof can become more successful, gain more acceptance and becomes simpler.

Government should provide or continue to provide fund or assistance to projects on green roofing in urban cities because at the long run it saves cost.

At last green roofing is an important factor that cannot be neglected when trying to achieve sustainable environments because of its numerous importance to urban areas and the world at large.

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