# ASSESSEMENT OF SUSTAINABLE ECO-FRINEDLY GREEN BUILDING STRUCTURES AND ITS PROMOTION IN KAMPALA

**FINAL YEAR PROJECT REPORT**

**By**


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**SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING IN PARTIAL FULFILLMENT FOR THE AWARD OF ABACHELORS DEGREES IN CIVIL ENGINEERING OF KAMPALA INTERNATIONAL UNIVERSITY**

## DECLARATION

We hereby declare that all the information in this project report is out of our own effort and that any other assistance we received in its preparation and compiling is fully acknowledged and discussed.

We also certify that we prepared this project report scientifically for the partial fulfillment for the award of Bachelor of Science in civil engineering to the School of Engineering and Applied Sciences at Kampala International University.

Also, this proposal has never been submitted before to any other institution for a ward of any qualification and any occurrence of a similar report will be an unfortunate coincidence.

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## APPROVAL

The undersigned certifies that, he has read through and here by recommended for acceptance by the Kampala International University – Department of civil and Mechanical Engineering in partial fulfillment for the requirements of the award of Bachelor's Degree in Civil Engineering.

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## DEDICATION

We dedicate this report to the Almighty God without whose grace, this final year project would not have been possible, our parents who have inspired us to go to school, may God grant them the opportunity to live longer and all our friends and course mates with whom we have enjoyed for all the four years of study and may God help us to live to serve the nation.

## ACKNOWLEDGEMENT

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**ABSTRACT**

The construction industry consumes about forty percent of the world's energy. The high increasing rate of construction activities has led to exploitation of most of the natural resources. These activities have led to massive deforestation and clearing of green cover for settlement and infrastructure development in Kampala. The repercussions of these activities are catastrophic such as poor air quality, urban heat island effect, toxic gas emission, increased cooling costs, which later affect people's health.

The study mainly aims at introducing and making aware to the public a technology that can be used to eliminate most if not all the environmental problems listed above. The green roof technology has been in use since the ancient days such as the Babylonian gardens. The green roof technology is currently being used and promoted in most developed countries such as; Germany, USA, Switzerland and Australia as a key component to sustainable development.

The main objective of this study is to assess the feasibility of adopting the green roof technology our building in Kampala capital city. Specifically carrying out literature review on major benefits of a green roof, to assess its cost analysis and carrying out a market research for green roof materials.

The results of the study were; the green roof has quite a number of benefits such as storm water management, habitat for wild life, noise attenuation, improved air quality, reduction in greenhouse gases. The initial cost of installing a green roof was found to be more expensive than the conventional roof. However, the benefits of the green roof were found to outweigh the initial costs of installation in the long run.

## LIST OF ACRONYMS

| | |
|---|---|
| A/C | Air conditioner |
| BTU | British Thermal Units |
| EPA | Environmental Protection Agency |
| kW | Kilowatts |
| NEMA | National Environment Management Authority |
| UBOS | Uganda Bureau of Statistics |
| kN | Kilonewtons |
| Ush | Ugandan shillings |

# CHAPTER 1: INTRODUTION

## 1.1 BACKGROUND

A green roof is one of the most important components of a green building. A green building is an environmentally sustainable building designed, constructed and operated to minimize the total environmental impacts. Environmental sustainability on the other hand refers to meeting the needs of the present generation without compromising the ability of the future generations to meet their own needs (World Commission on Environment and Development, 1987).

With the high increasing rate of construction worldwide, about fourty percent of the world's resources and energy is being used for construction and maintenance of buildings (Jamilus et al., 2013). This is a very high percentage which has caused a lot of destruction in the environment today. Such destruction includes; air pollution, deforestation, and destruction of the biodiversity, natural habitats and natural resources. The construction industry has therefore been regarded as one of the largest polluters to the environment (Jamilus et al., 2013). The final results of these activities affect the human health and lead to global warming at large. From numerous research that has been done, it is anticipated that the introduction of green elements into building structures will facilitate in percentage reduction of resources and energy used in the construction industry. On top of this it will help in reducing environmental pollution caused by construction activities.

Using the green building approach in the construction industry will help in reducing its negative impacts on the environment as it mainly seeks to increase the energy efficiency of a building structure. Jamilus (2013) found that green building practices are capable of reducing energy consumption by a half, 61% of carbon emission, 60% of water used and 30% of solid waste. The green building technology is an old technology which has been greatly applied in most of the European countries such as Germany, Australia, Switzerland and also in the United States of America (USA). Kampala as a capital city needs to adopt this technology since it has been widely used in developed cities to mitigate environmental degradation caused by construction activities.

Kampala is the capital city of Uganda located in the central part of the country. Uganda being a developing country with an economic growth rate of 4.6% in the financial year 2015/2016 (UBOS, 2016), there is a high rate of infrastructure development. The construction activities involved have caused emission of toxic gases into the atmosphere massive and destruction of the green cover in substitution for construction purposes. The high numbers of buildings have alongside them access roads with impermeable paved surfaces which affect storm water management in the city. The large areas of impermeable paved surfaces and poor drainage systems are the major causes of floods in the city. The construction industry in Kampala has not fully utilized the emerging sustainable green building technologies in increasing the energy efficiency of the building structures. The highly used traditional practices in construction management and processes have failed to control unforeseen challenges like carbon emission hence there is need for the different stakeholders to rethink and improve the processes and technologies used in construction (Jamilus et al., 2013).A green building consists of several components such as: green roofs, green walls, green balconies, solar and rainwater harvesting systems. From the various research the has been carried out on each individual component, researchers made a collective agreement that “one way of reducing the impact of global warming is by implementing the Green Roof Technology”, (Jamilus et al., 2013),. This makes the green roof technology more credible for this research. The green roof technology integrates vegetation, growing medium and water proofing membrane on top of the roof surface (Ashish&Rinku, 2012).

## 1.2 PROBLEM STATEMENT

Kampala being the case study with a high population growth rate, there is a high demand for settlement space which has forced people to clear away the green cover in search for construction space. In addition to the high rate of industrialization, the results of these activities have led to accumulation of toxic gases and air pollution in causing employee discomfort hence low productivity in the city. In conclusion the construction industry is using a lot of natural energy for its activities. This has caused more destruction to the natural vegetation without replacement leading to environmental degradation.

## 1.3 JUSTIFICATION

Over the past 25 years 60% of the world‘s major ecosystems have been degraded and used unsustainably, including thorough decline in soil quality, land degradation and deforestation due to construction works. According to OECD, (2012a), the global terrestrial biodiversity is projected to decline by a further ten percent by 2050. So we as engineers have to come up with self-contained building designs that incorporate green plants on them. The use of this technology will improve on storm water management, prevent causes to climate change and could also be used for growing crops and vegetation.

## 1.4 OBJECTIVES

### 1.4.1 Main objective

The main objective of the study was to assess the feasibility of incorporating a green roof on a building structure.

### 1.4.2 Specific Objectives

1. To review the benefits of using a green roof as compared to the conventional roof
2. To determine the cost implication of incorporating the green roof in terms of extra materials.
3. To find out the availability of green roof materials on the local market

## 1.5 SCOPE OF STUDY

In this research study we have reviewed the key benefits of a green roof from available literature. A market survey was also conducted to determine the availability of green roof materials in the local market mainly within the city center. This whole study was conducted within Kampala region for a period of three months.

# CHAPTER 2: LITERATURE REVIEW

## 2.1GREEN ROOF DEFINITION

In simple terms a green roof refers to one with vegetation on top (Enright, 2013). These are nascent, novel and somewhat isolated with a growing medium and having plants on top. Their exposure to wind is very high which creates a niche with few potential natural analogues due to their shallow profiles and usual detachment from the earth's surface. The limited moisture restricts the capacity for a large diversity of species (Lundholm and Richardson, 2010; Sutton et al, 2012). The appearance of green roofs is a result of emerging ideas aimed at improving the built environment, evolving design techniques and advancements of building materials (Getter and Rowe 2006; Weiler and School - Barth 2009).

## 2.2 HISTORY OF GREEN ROOF TECHNOLOGY

Green roofs and roof gardens have been in use since a thousand years ago. There has been very little survival of the physical evidence of green gardens despite their recorded evidence (Osmundsen, 1999).

According to Peck et al., (1999), Trees were incorporated on top of many institutional buildings some of which are the mausoleums of Augustus and Hadrian by the Romans. A clear evidence of the ancient green roof and garden technology can be seen from the hanging gardens found in Babylon which exist in the Roman Empire. Shopkeepers also grew vines on the upstairs of their balconies in Pompeii. According to ancient historian Pliny, trees were transported for green roofs. The city of Genoa was also well known for steeply terraced gardens and green roofs during the renaissance. Vertical gardens in the form of hanging gardens existed in India, pre-Columbian Mexico and in some of the Spanish homes of 16th - 17th century. These gardens were highly favored in the 17th century in Russia. Green roofs and hanging gardens were established on homes in many twentieth century countries (Peck et al., 1999).

The rapid urban environmental degradation and decline of green space in intensely developed areas has seen the green roof and vertical gardens widely being adopted in the North Europe; particularly in Germany, Switzerland, Austria, and Scandinavia.

The development and enhancement of the terraced green roof technology mainly took place in the early 1960s in many countries like Germany and Switzerland in particular. Significant amount of technical research was carried on in the 1970's on the different green roof components such as; waterproof membranes, drainage, light weight growing media, plants and studies on root repelling agents.

## 2.3THE MODERN GREEN ROOF

The modern green roof technology was given birth to in 1960s from both Germany and Switzerland after carrying out lots of research on the technology (Halil and Ahmed, 2016). Reinhard Bornkamm who was a German researcher later on published his works on green roof in 1961which really gave a better understanding on green roof technology. Within the same year of 1961, the Geno Haus was also built in Germany which remained functional until 1990 according to the Metropolis Magazine. In 1970 some important researches were carried out on the green roof components like, root repelling agents, water proofing membrane, growing media and drainage. The green roof markets in Germany rose rapidly with an annual growth of fifteen to twenty percent in 1980 by 1989, about one million square meters of green roof was installed in Germany which later rose up to ten million square meters by 1996. Such rapid development was a result of enormous help and encouragement from the Germany government through contribution of about thirty five to forty five deutsh marks per square meter of each installed green roof. A new green roof industry was given birth to through the incorporation of roof and vertical greening in the planning regulations of cities in most European countries. The industry is responsible for providing the green professionals, installers, maintenance crew and supply of plant and materials. Countries like Germany, France, Austria, Norway, Switzerland and other European states have made the incorporation of green roofs in buildings a common practice in their construction industry and urban landscape (Peck et al., 1999).

From the wide experience, guidelines were developed based on academic research, product/component development, and field observation (Dvorak, 2010). These guiding principles were developed by the German Landscape Research, Development and Construction Society in 1995 and published in German in 1982 and in English in 2002.

In the world today, the popularity of green roofs is increasing in the United States of America with it being highest in German with about 14% of their flat roofs having green plants (Getter, 2006). In the early days before the urbanization and human developments, soils and vegetation were used to control storm water and solar efficiency. However in the current state green roofs have been one of the most effective storm water and solar efficiency control systems. The Association of Standards and Testing Materials (ASTM) in the United State of America have devised green roof guiding principles which are quite different from the German Landscape Research, Development and Construction guidelines in German. These guiding principles are mainly used for the selection of green roof plants, maintenance, and requirement for structural load and green roof layers (Dvorak, 2010).

## 2.4GREEN ROOF POLICY AS A SUSTAINABLE PRACTICE

Policies are descriptions, explanations and advocations to how humans should act in organizing themselves. Policies are future oriented meaning they promote features and actions that are anticipated to occur (Sutton, 2015).

The World Commission on Economic Development (1987) stated sustainable development policy as “development that meets the needs of current generations without compromising the ability of the future generations to meet their own needs”.

Policies often form the basis by which discussions about the allocation of public resources are focused and officially validated (Sutton, 2015). For example the Clean Water Act at Federal Level in United States provides a stimulating factor to local separations for improving rain water discharges (Carter and Fowler, 2008).

Once the policies are officially validated in the local context, they are crafted into laws, ordinances, and finally reflected in building codes or other types of standards (GRHC, 2006b). According to Dvorak (2011), local policies can either frustrate or facilitate green roofs as a sustainable building practices.

Carter and Fowler (2008) and Simons et al.(2009) provide some of the techniques used in encouraging the green movement mainly aimed at promoting green roof implementation as: tax incentives, revised building codes that simplify structural weight-loading requirements, tax incentives, reduction on fees, fast-tracking the development process, density bonuses, and outright/wholly grants.

## 2.5 DEFINITION OF SOME TERMS

### 2.5.1 Green Roof

A green roof can be defined as a roof that is fully or partially covered with plants or vegetation on a normal iron sheet or concrete decked roof (Dvorak, 2010). A green roof has several layers with the top layer being 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, Ouldboukhitine et al, 2011).

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

### 2.5.2 Green Roof Types

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

#### 2.5.2.1 Extensive Greening

The extensive green roof is simpler compared to intensive green roof because of its lightweight and low-maintenance requirements. It uses a drought resistant plant of sedum specie. The extensive green roof has a thickness of less 150 mm and can weigh from 73kg/$m^2$ to 122 kg/$m^2$according to Breuning (2015). Looking at extensive green roof from sustainable point of view it's considered to be more important because of its low weight and more application on rooftops as compared to the intensive type (Benvenuti, 2010). When elements of both extensive and intensive green roof are found in green roof then it's considered to be semi intensive green roof (Ampim, 2010).

Soil is generally 4" to 6" deep which involves cultivation of vegetation in forms that create a 'virtual nature' landscape and requires hardly any external input for either maintenance or propagation. The plants used are particularly well suited to cope with the full range of conditions which are likely to be encountered at the locations in which they are planted while considering the local flora hence making them capable of self-propagation. Extensive green roofs are usually planned to require irrigation only during the first one to two year start-up period. The kind of irrigation varies with plant selection, micro climates and age of plantings.

#### 2.5.2.2 Simple Intensive Greening

Soil is generally 8" to 12" deep. As a rule, simple intensive greening involves the use of grass, shrubs and bushes as ground cover, but the range of options available to the user and the architect is not as wide as that intensive greening has to offer. The plants which are used make few demands on the layering superstructure and need little watering and feeding; this reduces the amount of attention required. Depending on the range of plants, regular irrigation may be required beyond the start-up period. A simple intensive greening site is typically less costly to construct than it is for intensive greening site.

#### 2.5.2.3 Intensive Greening

Intensive green roof is the type of green roof that contains different types of vegetation starting from grass, shrubs to small trees. It's often in roof gardens and may also include walkways, benches, tables, and fountains on the roof. The intensive green roof has a depth greater than 150mm with a heavy weight which requires 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 – 391kg/$m^2$ according to Breuning, (2015)

Intensive hard landscaping and planting in the inner and outer gardens. Planter substrate depth: 750mm. Intensive soft landscaping of the apex garden. Apex substrate depth: 200-750mm.

Soil is greater than 12" deep. The term 'intensive greening' covers the planting of shrubs and bushes, as well as grassed areas, even an occasional tree. These may be laid out either on the same level, at different heights or in individual plantings spread about the site. The wide range of options available for designs and uses means that sites can be fitted out in such a manner as to create an amenity comparable to park facilities at ground level. The plants which are used make heavy demands on the layered superstructure. Regular attention is needed to maintain sites of this type in good order, in particular regular watering and feeding is required. Intensive green roofs are most typically used in plaza applications.

#### 2.5.2.4 Modular Vegetated Roofs

A modular vegetated roof is composed of a series of pre-planted modules typically made of recycled plastics that can be placed directly on a roof or other structure with sufficient structural capacity. A protection board/course is typically placed over the existing or new roofing membrane prior to placement of the modular trays. The modular trays are designed to be a complete self-contained system and are typically pre-planted. The benefits of modular systems are easy and quick installation. The modulars are typically light weight which allows them to be moved for repair and set back into place. The vegetation in the modulars are typically preplanted and pre-grown to give the immediate benefits of an established vegetated roof.

### 2.5.3Extensive Vs. Intensive

Green roofs come in all shapes and sizes with a great variety of the shrubbery. For instance, a green roof could be as simple as a 2-inch covering of hardy, alpine-like groundcover, which is an example of an extensive system, or a complex as a fully accessible park complete with trees, which is an example of an intensive system (EPA, 2013). Extensive green roofs generally contain lighter weight variety of plants suitable for an alpine environment.

The goal is to design a system that requires as little maintenance or human intervention as possible. Furthermore, plants that can adapt to extreme climates tend to make good choices.

These systems are the most cost-effective since their lightweight nature requires the least amount of any added structural support for the roof (EPA, 2013). On the other side of the spectrum, an intensive green roof could be seen as a man-made park or extravagant garden. These systems have the greatest variety of available plants, including trees and shrubs. Intensive green roofs are more popular with larger scale buildings and businesses that want to see an economic benefit in the long-term to save on energy costs and extending the life of their roofs. In addition, these intensive green roof systems add to the aesthetics of the building, which allow for occupants and the general public to enjoy. However, intensive green roof systems are heavier and require more initial investment along with more maintenance over their lifetime and require a greater deal of structural support to accommodate their weight (EPA, 2013). No matter the nature of the green roof system, they are composed of generally the same components whether extensive or intensive.

## 2.6 PHYSICAL COMPONENTS OF A GREEN ROOF

### 2.6.1 Vegetation

Deciding on which type of vegetation to include in the green roof system depends on many factors: extensive vs. intensive, building design, local climate, available sunlight, irrigation requirements, and anticipated roof use. Extensive systems tend to have hardy perennials with shallow roots, which require minimal nutrients. Intensive systems, on the other hand, contain plants with deeper roots and tend to require irrigation systems that support a wider variety of plants and shrubbery (EPA, 2013).

### 2.6.2 Growing Medium

There is an ongoing debate on which green roof mediums to utilize. Many sources have come to a conclusion that the medium should at least last as long as the roof that it covers.

Soil does not necessarily need to be the primary organic matter. Different companies have their own formula and mixture for the mediums used for their systems (EPA, 2013).

**Filter Membrane, Drainage Layer, and Root Barrier**

The membrane acts just like a filter. It catches small particles from the excess water that pass through the growing medium. The drainage layer helps the water from the medium to flow to the roof drain. The root barrier protects the roof from excessively long and harmful roots that may damage it (EPA, 2013).

Water Proofing Membrane: The waterproofing membrane’s function is to protect the roof from water penetration. The cover board adds an extra layer of protection for the roof from water. The thermal insulation also provides an added layer of protection from moisture while simultaneously insulating the roof for energy conservation. Finally, the vapor barrier also assists in a final layer to protect the roof from any excess water or moisture from the other layers (EPA, 2013).

Reducing Urban Heat Islands: In regards to combatting urban heat islands, each system of green roofs works by providing shade to the surfaces of roofs and evapotranspiration. Transpiration is the process in which plants absorb water through their roots and emit it through their leaves.

Evaporation is the conversion of a liquid to a gas, which occurs in the surfaces of vegetation and the surrounding growing medium. These processes together are called evapotranspiration, which cools the air by using heat from the air to evaporate water (EPA, 2013). By installing green roofs on buildings in urban communities, they can help reduce the heat island effect and cool the air.

### 2.6.3Shading

The plants on the green roof along with the growing medium work together to block sunlight from reaching the roof, which in turn reduces the surface temperature of the roof. In addition, the plants absorb about 10 to 30 percent of the sunlight for photosynthesis. Furthermore, this combination reduces the amount of energy that gets transmitted back into the atmosphere, which causes a great deal of temperature increase in cities (EPA, 2013).

## 2.7 VEGETATED ROOF SYSTEM COMPONENTS

Although different manufacturers have different roof systems, the following is a general list of components that go into a vegetated roof system.

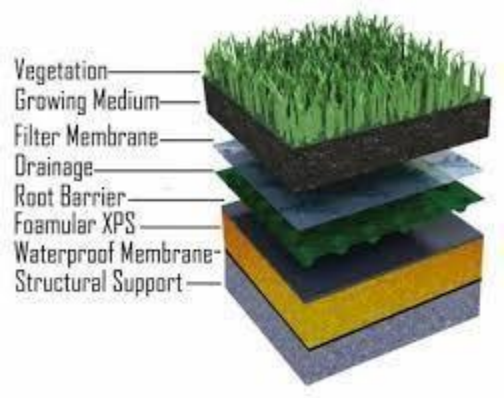


**Figure 1: A typical section through a green roof structure.**

i. **Roof Substrate:** Concrete is recommended however steel deck is generally adequate. Wood decking may be acceptable if sufficient load and deflection capacity are available.

ii. **Roof Membrane:** National Roof Contractors Association (NRCA) recommends waterproofing systems to be fully adhered to the substrate and be able to provide hydrostatic resistance based on the expected amount of water drainage and retention.

iii. **Protection Course:** Protects roof membrane from damage after installation of the waterproofing/roofing membrane.

iv. **Root Barrier:** A material that prevents plant roots from damaging the waterproofing membrane.

v. **Separation Layer:** Installed if necessary to keep chemically incompatible materials apart.

vi. **Anti-bonding Layer:** Prevents unwanted bonding between different materials and reduces shear stress levels between any pair of courses.

vii. **Drainage Layer:** Provides a location for moisture to move laterally through the green roof system and also relieves hydrostatic pressure from material's surface and the associated weight of water.

viii. **Water Reservoir Layer:** Retains or stores moisture for overburden growth. ix. **Water Retention Layer:** Retains or stores moisture for plant growth.

x. **Water-resistance Insulation:** Extruded Polystyrene Foam Insulation, R-value of 5.0 per inch thickness, specify R-value to meet Massachusetts building and energy codes.

xi. **Filter Fabric:** Tightly woven fabric used to restrict the flow of fine soil particles and other contaminants while allowing water to pass freely through, thereby protecting the drainage systems from clogging.

xii. **Growing Media:** An engineered soil-based medium, specially formulated to provide a proper growing environment for the specific plants.

xiii. **Vegetation:** Selected according to climate and geographical location; plants may include moss, sedums, small to large shrubs, coppices, grass, and small to large trees.

xiv. **Erosion Mat:** Mat/blanket to control erosion while plants are established, often made from natural materials like jute or core; biodegradable as plants establish themselves, and provide an important layer of mulch to retain moisture and suppress weeds in the process.

xv. **Wind Net:** Net to control wind uplift of the growing medium and plants depending on the design wind loads calculated for the building.

# CHAPTER 3: METHODOLOGY

This chapter demonstrates the methods used in achieving the specific objectives stated above. The stated specific objectives aim at having eco-friendly green storied buildings that are environmentally sustainable to reduce on the environmental problems to a small percentage or completely zero.

## 3.1 EVALUATION OF GREEN ROOF BENEFITS

The significance of using green roofs as compared to conventional roofs was achieved by making a thorough desk study of the existing literature on green roof structures. Information was mainly obtained from published academic journals and articles related to green roof technology.

## 3.2 COST ANALYSIS

This is the amount in monetary terms that has to be given up or paid to get something. The reason for carrying out this analysis is that for every project or innovation to be successful it must be cost friendly. This being a new technology in the region calls for a thorough study on the costs associated with it. Well, to buy the idea of going green on building rooftops has some consequences in terms of cost associated with it. This has to be determined such that one is able to make a rational decision of either or not greening the rooftop. The cost will be as a result of additional material required to support the green roof components.

## 3.3 MARKET SEARCH

There are two basic types of information that can be gathered when conducting primary research and these are, exploratory research which is open-ended which involves unstructured interviews with lengthy answers from a small group of respondents, specific research on the other hand is precise in scope with structure and formal interviews. For the case of our study we used both the exploratory research because most people were found to be naïve about the topic hence this method would work best and the use of a questioner was adopted for structured and formal interviews. This involved the physical movement to markets, stores and shops that deal in hardware and construction materials specifically in Kampala. Informal interviews and one on one inquiries were made in order to capture different aspects of data such as knowledge about green roofs, can the technology be supported and why? However, our main objective was to find out which green roof materials are available and where.

Some of the markets visited were Shauryako, Hardware City and Nakasero, Roofing’s, fase industries ltd outlets and industrial area.

# CHAPTER 4: RESULTS AND ANALYSIS

## 4.1 MARKET

The results show that people are not well informed and engaged in the green roof technology. However, they have an idea of the modular vegetated roofs which consists of buckets having green plants in them and installed on rooftops. There are few green roof materials on the local market since this has not been a common practice in Kampala. However some of the material can be manufactured on special orders to the manufacturing industries. It is expected that the kickoff of this technology will be another business venture in the construction industry.

From the study, materials that can be readily available in any quantity needed are drainage mats (2x1m @80,000/=), drainage plates, pvc drainage channels/gutters (@30,000/=), filter fabric (Some materials can also be got on special order from manufacturers). According to the contractors approached, green roof materials can be purchased from abroad such as Germany, India and USA.

| LAYER | MATERIALS | WEIGHT(kg/sq.ft) | THICKNESS(in) |
|---|---|---|---|
| Water proofing | Bituminous fiberglass reinforced waterproofing | 0.32 | 0.14 |
| Root barrier | Polyethylene (LDPE) | 0.07 | 0.06 |
| Water retention | Recycled polyester fibers | 0.11 | 0,39 |
| drainage | Drain max 200 series | 0.07 | 0.25 |
| filter | Non woven polypropylene | 0.01 | 0.02 |
| substrate | Roofline extensive 500 soils | 8.18 | 3.94 |

***TABLE 1.*** shows how much of the materials per each layer required

## 4.2 COST ANALYSIS

### 4.2.1 DESIGN AND IMPLEMENTATION OF GREEN ROOFS.

The design and implementation of green roof projects is relatively straight forward, provided the following issues are considered and dealt with. Like any project (site), each building, each building owner and each end user is different, so each individual green roof project will vary from the other.

### 4.2.2 DETAILED COST ESTIMATES AND VARIABLES

Although green roofs systems share common components ,there are no standard costs for implementation. The two tables below give a range of the component costs and indentify some of the key variables that determine these costs.

INACCESSIBLE EXTENSIVE GREEN ROOFS.

Cost assume an existing building with sufficient loading capacity , root hatch and ladder access (the larger the green roof ,the cheaper the cost on a square meter basis)

| **components** | **cost** | **Variables** |
|---|---|---|
| Design and specifications | 5% -10% of the total roofing project cost | The number and type of consultants required, depends on size and complexity of the project |
| Project administration and site review | 2.5% - 5% of the total roofing project cost | The number and type of consultants required, depends on size and complexity of the project |
| Re-roofing with roof repelling membrane | Ush 400000 – ush 640000 (per sq meter) | Cost factor include type of the existing roofing to be removed, type of the new roofing system to be installed, ease of roof access and nature of flashing required |
| Green roof system (curbing drainage , filter cloth, growing medium | Ush 22000 – ush 440000 (per sq meter) | Cost factor include , type and depth of the growing medium ,type of curbing ,and size of the project |
| plants | Ush 44000 - ush 128000 | Cost factor include, time of year, type of plant and size of plant, seed ,plug or pot |

| | | |
|---|---|---|
| Installation / labor | Ush 128000 – ush 344000 (per sq meter) | Cost factor include, size of the project, equipment rental, complexity of design and planting equipment |
| maintenance | Ush 52000 – ush 84000 (per sq meter) | Cost factor include size of the project, timing of installation, irrigation system, and size and type of plants use |

ACCESSIBLE INTENSIVE GREEN ROOFS

Cost assume an existing building with sufficient loading capacity , root hatch and ladder access

(the larger the green roof ,the cheaper the cost on a square meter basis)

| **components** | **cost** | **variables** |
|---|---|---|
| Design and specifications | 5% -10% of the total roofing project cost | The number and type of consultants required, depends on size and complexity of the project |
| Project administration and site review | 2.5% - 5% of the total roofing project cost | The number and type of consultants required, depends on size and complexity of the project |
| Re-roofing with roof repelling membrane | Ush 400000 – ush 640000 (per sq meter) | Cost factor include type of the existing roofing to be removed, type of the new roofing system to be installed, ease of roof access and nature of flashing required |
| Green roof system (curbing drainage , filter cloth, growing medium | Ush 640000 – ush 1280000 (per sq meter) | Cost factor include , type and depth of the growing medium ,type of |

| | | |
|---|---|---|
| | | curbing ,and size of the project |
| plants | Ush 216000 – ush 8600000 (per sq meter) | Cost factor include, time of year, type of plant and size of plant,seed ,plug or pot |
| Installation / labor | Ush 340000 – ush 780000 (per sq meter) | Cost factor include, size of the project, equipment rental, complexity of design and planting equipment |
| maintenance | Ush 54000 - ush 86000 (per sq meter) | Cost factor include size of the project, timing of installation, irrigation system, and size and type of plants use |

The final calculation for this study revealed important implications of green roof design. The area, depth, weight and cost of the green roof were termed

| LAYER | COST PER sq. FEET (SHS) |
|---|---|
| Water proofing | 1320 |
| Roof barrier | 840 |
| Water retention | 200 |
| Drainage | 1720 |
| Filter | 280 |
| Substrate | 6360 |

***TABLE 4.*** Shows the cost of materials of a layer of green roof per area in feet.

### 4.2.3 Maintenance

Green roof maintenance is crucial especially in the first 5 years after establishment. Maintenance of the green roof for the first 5 years after installation is often included in a green roof installation contract. According to a study carried out in Minnesota, the maintenance costs for an extensive green roof varies from \$0.0093-\$0.093 per sq. meter per year after the first 5 years. This is equivalent to (Ush) 354/= per sq/year which totals to 16,567,200/= for a period of 90 years.

#### 4.2.4 Conventional roof replacement

From literature it is evident that most roof membranes such as iron sheets last for not more than 20 year beyond which they must be replaced to restore their functionality. However, according to Kohler, 2003 green roof can survive up to 90 years. This means green roof lifespan is four times that of a conventional roof. A square meter of vinyl roof membrane would cost about 33,000/= which totals to 18,480,000/= for the whole roof. For a lifespan of 90 years the cost of replacement would be four times which is equal to 73,920,000/=.

#### 4.2.5 Savings on air conditioning

Cooling capacity is measured in British thermal units. In terms of power (BTU/hr), it is equivalent to $2.93x10^{-04}$ kWhr. Basing on a two occupant room, the cooling capacity required for a $30m^2$ room is 8000 BTU/hr. This means the rate of cooling is 267 BTU/hr (0.0782kWhr) per sq. meter. Assuming 5hr of cooling is required per day then 0.39kWhr/m/day. For the total roof area of (40x14) $m^2$ the cooling provided would be 218.4kWhr/day. At a unit price of 650/= per kW the savings on cooling per day would be 141,900/= per day. Assuming five working days per week this would save 34,056,000/= per year. For a period of 90 years a green roof would save 3,065,040,000/=.

### 4.3 BENEFITS OF GREEN ROOFS

Green roofs are one of the most readily-accessible sustainable technologies available to the construction industry and can be included as part of new buildings and (subject to structural checks), retro-fitted to existing buildings to provide the following benefits to the occupants of buildings, as well as the local setting. (Code of practice for the UK 2011)

#### 4.3.1 Storm water management

Urban areas are highly characterized by hard, nonporous surfaces which contribute to heavy run off. This leads to damages to the existing storm drains causing sewer overflows into lakes and rivers. Alongside causing floods, erosion and sedimentation, urban runoff in addition contains pollutants such as pesticides and petroleum residues which become harm full to wild life habitats and contaminate drinking water (Moran et al. 2005). Traditionally swamps, storage reservoirs, ponds and sand filters have been used as the conventional storm-water management techniques. However due to the large surface areas needed for these, it is difficult to implement these techniques in dense urban centers (Mentens et al. 2005). The green roof idea becomes more credible for urban storm-water management as they make use of the existing roof space. According to Moran et al, 2005 green roofs with more than 10cm of substrate retain about 66%69% of rainfall which delays the runoff until after peak rainfall hence preventing floods. Though green roofs reduce runoff, they do not solve reduced ground water recharge problems in urban areas (Erica et al, 2007). The chart below shows that a green roof is able to retain about 60% more rainfall water than the conventional roof.

| Water Retention for Traditional Roof vs. Green Roof | | |
|---|---|---|
| Rainfall Retained % | Standard Roof | Green Roof |
| Average Retention | 24% | 80% |
| Retention at Peak Runoff | 26% | 74% |

Chart showing average water retention for a traditional roof vs. a green roof. *Source: "Green Roofs in the New York Metropolitan Region, Research Report," Rosenzweig, et. al*.

Having seen the various reasons projected to promote public policies which include green roofs as part of sustainable building development (Getter and Rowe, 2006), several benefits for both private and public green roofs are realized (Green Roofs for Health Cities, 2006a; Bernardi et al., 2013).

Green roofs are better than conventional impervious roof tops when it comes to storm water management as they retain much more amount of precipitation. The retained precipitate is either returned to the atmosphere by evaporation or slowly drained to the ground (Bates et al. 2009; Berndtsson 2010; Morgan et al, 2012). This action reduces the quantity and intensity of storm water hence preventing occurrence of floods. Schroll et al. (2011); Gregore and Clansen (2011) say that the retarding and runoff detention greatly relies on the type of roof vegetation, substrate volume, its composition and the nature of storm event. The interception and detention of storm water by green roofs helps in partial water treatment hence such water can be designed to flow into cisterns, rainwater gardens, bio-swales and detention ponds. According to

Berndtsson et al. (2009), green roofs remove atmospheric pollutants and nutrients from precipitation prior to their discharge into streams or lakes.

### 4.3.2 Improving the roof membrane longevity

The ultraviolet (UV) radiations facilitate the rapid deterioration of water proofing membranes. The radiations produce fluctuating temperatures that cause both contraction and expansion of the roof membranes leading to their damage. According to USEPA (2000) it is anticipated that the useful life of a waterproofing membrane may be prolonged by 20 years. This is evidenced by some green roofs in Berlin that have lasted over 90 years without any major repairs (Porsche and Kohler 2003). Hence green roofs protect such membranes from deleterious effects and may double their life span and reduce the amount of worn out membrane that enters the landfill (Carter and Keeler, 2008; Bianchini and Hewage, 2012). An unvegetated reference roof in Ottawa, Canada reached temperatures higher than $70^0$C as compared to $30^0$C reached by the green roof (Liu, 2004). Therefore green roofs are expected to reduce the general temperatures in building structures.

### 4.3.3 Urban heat Island Effect

This is a condition where urban regions are significantly warmer than the surrounding suburban and rural areas especially at night as can be seen from the graph. This comes as a result of replacing the vegetation with dark and impervious surfaces such as asphalt roads and roofs in urban environments. By reflecting and diverting solar radiations from reaching these surfaces using vegetation cover this effect can be reduced (Erica et al, 2007). A simulation model carried out by Bass et al. (2002). Using 50% green roof coverage throughout Toronto shows a $2^0$C temperature reduction in some areas. The graph below shows a comparison between the average temperatures of both greened and non-greened roofs. It can be seen that for a non-green roof temperatures go as high as $65^0$C as compared to $30^0$C for green roof.

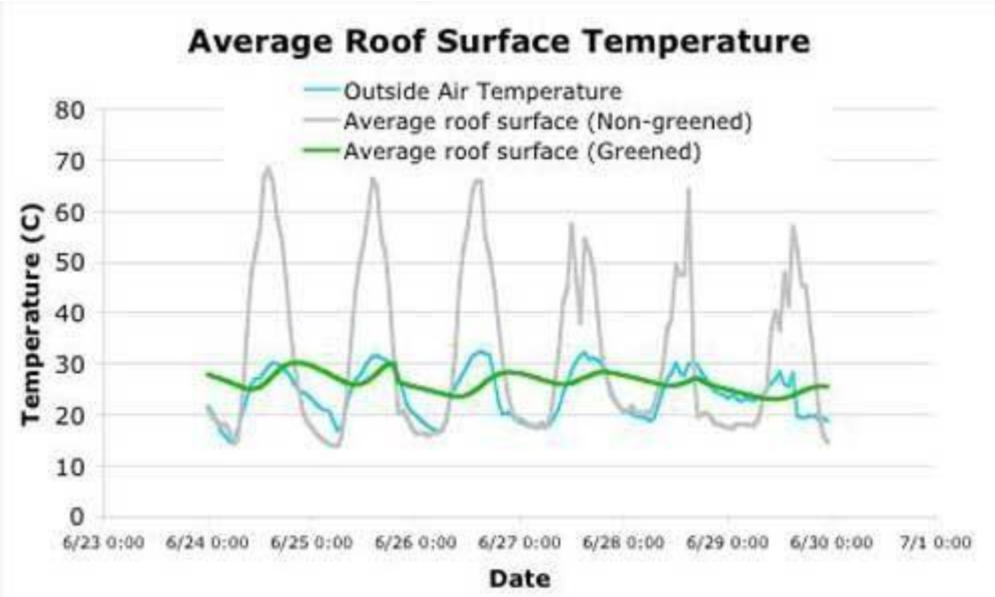


**Figure 2: Graph showing average roof surface temperatures for both "greened" and "non-greened" roofs. Source: Penn State Center for Green Roof Research.**

### 4.3.4 Energy reduction

Green roofs aggregately affect the building's and city's energy budget as it significantly reduces the building's ambient temperatures during summers (Smith and Roebber, 2011; Gaffin et al. 2008). Since green roofs act as insulators they cut down on the operational costs required for summer cooling and winter heating for individual buildings (He and Jim, 2010; Feng et al. 2010).

### 4.3.5 Reduction of greenhouse gas emission

The addition of vegetation to urban landscape increases photosynthesis and oxygen production which reduces carbon dioxide level produced by vehicles, industrial facilities and mechanical systems. (National Park Service U.S. Department of the Interior)

### 4.3.6 Improved air quality

Erica, (2007) stresses out that the urban vegetation is known for trapping airborne particulates and taking up contaminants such as nitrogen oxides. Extensive green roofs can make significant urban carbon sinks even though they have little potential combat carbon emission from cities as compared to intensive green roofs.

### 4.3.7 Urban habitat values

The displacement of living space for plants (Cook-Patton and Bauerle 2012; Madre etal. 2014) insects (MacIvor and Lundholm 2011), and birds (Coffman and Waite 2011) is mitigated by using green roofs which reestablishes their habitat. For example the flowering plants on top of green roofs allow for the introduction of bees and support other pollinators. Though green roofs cannot wholly replace the biodiversity and complexity of intact ecosystems, at least they prevent some of the changes and may supply living corridors for insect and bird movement in cities. The aesthetics of green roofs goes beyond merely pleasure than might be experienced in view the surface features of any garden (Sutton, 2014).

### 4.3.8 Noise attenuation

Green roofs serve as noise attenuators because of their porous mass (Connelly and Hodgson, 2008) and depending on their depth and composition they can reduce noise impact from an overhead source such as airliner up to ten decimals.

# CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

## 5.1 CONCLUSION

The study aimed at finding out some of the key benefits of a green roof, bill of quantities both with and without the green roof, cost analysis and market research. From the study, the following conclusions were made.

- It is evident that the green roof technology is gaining momentum in most developed countries such as Germany, USA, Switzerland, India and it is the trend for the next generation.
- The green roof has got numerous benefits that can help mitigate most of the problems faced in the construction industry such as; floods, energy exploitation, environment destruction, .
- The initial cost of green roof would be 374,000/= per sq meter which is higher than for the normal conventional roof however in the long run the benefits outweigh the costs.

## 5.2 RECOMMENDATIONS

- This technology must be incorporated in most of the structural designs so that we can have green healthy cities.
- Thorough study must be done to find out the most suitable growing medium in the native regions.
- Thorough studies must also be conducted on the most suitable green roof plant that can survive in the native climate.
- The government should provide incentives to facilitate the use of the green roof technology because it benefits the country at large.
- The construction industry must take on this technology because it is the trend for the next generation.

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## APPENDIX 1: RESEARCH QUESTIONNAIRES

# FACULTY OF ENGINEERING

## DEPARTMENT OF CIVIL ENGINEERING

### RESEARCH ON GREEN ROOF MATERIALS IN KAMPALA

**QUESTIONNAIRE FOR THE RESPONDENTS**

Please tick on the appropriate answer

1. Do you know about green buildings

   Yes No

2. Do you have materials that can be used in the green building .

Yes No

3. Are these material readily available.

Yes No

4. If these materials are not readily available what are some of these materials do you have.

   A. Waterproof membrane (bituminous fiberglass reinforced water proofing)
      Yes No

   B. Root barriers ( foamular xps, polyethylene)
      Yes No

   C. Drainage pipe ( pvc pipes, drain max 200 series)

      Yes No

D. Water retention (recycled fibers)

Yes No

E. Filter (Non woven polypropylene)

Yes No

5. What are some of the local materials do you have on market. List the materials that you have in your hard ware

A. ……………………………………………………………………………………………………
B. ……………………………………………………………………………………………………
C. ……………………………………………………………………………………………………
D. ……………………………………………………………………………………………………
E. ……………………………………………………………………………………………………

6. How can some one get the rest of the materials for green roofs.
   A. It can be brought on specialorders
   B. Hard wares can bring it for you