Effect of Green Roof in Thermal Performance of the Building
An Environmental Assessment in Hot and Humid Climate

تأثير الأسقف الخضراء علي الأداء الحراري للمباني
تقييم بيئي في المناخ الحار و الرطب

By

Elmira Jalali Saeid

Student ID 70140

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Professor Bassam Abu-Hijleh

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Abstract

This study is an evaluation to the environmental impacts of green roof in thermal performance of the residential building in the hot and humid climate of Dubai, the United Arab Emirates. A computer simulation Ecotect is utilized to measure selected parameter: the solar radiation of the roof, which means to measure the heat transfer from the roof into the buildings and the other simulation, is with different mathematical formula.

This study is carried out in four steps: first step, two types of residential buildings has been selected and simulating the internal solar gain of each building (building with conventional roof and building with green roof). The second step, simulating the U-value of both roofs (conventional roof and green roof), and find out which one has greater U-value and better insulation. Therefore, the internal solar gain of green roof with U-value has been smaller than conventional roof. The third step, find out the heat capacity of water and simulating the evaporation. And find out the benefits of evaporation. And finally, by creating a green roof layered with different thickness of the soil and local plants on the top of the buildings can add natural beauty on the building and human health.

The first step concludes that by having the green roof on the top of the building can reduce the internal solar gain and heat transfer. The second step concludes that the U-value of green roof is lower that U-value of the conventional roof which means is better and the same time by having the green roof can maximize the insulation on the roof. The third step concludes that by having evaporation from the green roof can have reduced the cooling and minimized the internal solar radiation and finally by choosing the best thickness of the soil, vegetation and plants can achieve the best result for hot and humid climate such as Dubai.

Finally, the study suggests guidelines and recommendations of benefits of green roof in hot and humid climate. Furthermore, it extends recommendations of configuration to other different climates besides the hot and humid and also effect of green roof in urban heat island in order to overcome the limitations of the proposal results.

ملخص

هذه الدراسة هي تقييم للأثار البيئية للأسطح الخضراء علي الأداء الحراري للمباني السكنية في المناخ الحار الرطب لدبي بالإمارات العربية المتحدة. وفيها يتم إستخدام محاكاة بالحاسوب ECOTECT لقياس العامل المتغير المختار و هو الإشعاع الشمسي و ذلك لقياس النقل الحراري من الأسطح إلي المباني بالإضافة الي محاكاة أخري تستخدم فيها صيغة رياضية مختلفة.

أجريت هذه الدراسة علي أربع خطوات: الخطوة الأولى، و فيها يتم إختيار نوعين من المباني السكنية، أحدهما ذو سطح تقليدي و الآخر يستخدم فيه نظام الأسطح الخضراء، وبالإضافة إلي عمل محاكاة للإكتساب الشمسي لكل نوع من الأسطح.

الخطوة الثانية، و فيها يتم عمل محاكاة لمعامل التبادل الحراري U-VALUE لكل نوع من الأسطح (الأسطح التقليدية و الأسطح الخضراء) لمعرفة أيهما له قيمة معامل التبادل الحراري U-VALUE الأعلي و أيهما له قدرة أفضل علي العزل الحراري. و بناء علي ذلك تبين أن الإكتساب الشمسي الداخلي و معامل التبادل الحراري U-VALUE للأسطح الخضراء أقل منه بالنسبة للأسطح التقليدية.

الخطوة الثالثة، و فيها يتم تقدير السعة الحرارية للمياه و يتم عمل محاكاة للتبخر و معرفة فوائده.
و أخيراً، من الممكن إضافة جمال طبيعي ذو تأثير إيجابي علي المباني و صحة الإنسان عن طريق إنشاء أسطح خضراء بسماكات مختلفة لطبقات التربة و النباتات المحلية أعلي المباني.

الخطوة الأولي تخلص إلي أن وجود الأسطح الخضراء أعلي المباني يمكن أن يقلل من الإكتساب الشمسي الداخلي و الإنتقال الحراري. الخطوة الثانية تخلص إلي أن معامل التبادل الحراري U-VALUE للأسطح الخضراء أقل منها بالنسبة للأسطح التقليدية مما يوضح أنها أفضل بالإضافة إلي كونها تحقق أقصي قدر من العزل الحراري علي الأسطح. الخطوة الثالثة تخلص إلي أن وجود التبخر من السطح الأخضر يخفض من التبريد كما يقلل من الإشعاع الشمسي. و الخطوة الأخيرة تخلص إلي أنه يمكن تحقيق أفضل النتائج للمناطق ذات المناخ الحار الرطب مثل دبي عن طريق إختيار أفضل سماكات للغطاء النباتي و التربة و النباتات.

وأخيراً, تقترح الدراسة توجيهات و توصيات لفوائد إستخدام الأسطح الخضراء علي المناخ الحار الرطب. و علاوة علي ذلك فهي تقترح توصيات للترتيبات الملائمة لأنواع المناخ الأخري غير الحارة الرطبة و كذلك تأثير الأسطح الخضراء علي الجزر الحرارية الحضرية للتغلب علي القيود المفروضة علي نتائج الإقتراح.

Dedication

I dedicate this research to the readers and everyone who has interested in sustainability, especially green roof …

Acknowledgments

Everyone says: It's frightening sometimes to look in the mirror and see the evidence of that. So often, we don't take a moment to say what's in our hearts, and then, when it's too late, we wish we had.

While I was working on this dissertation, I have always dreamt of that moment when I would get to this part, when I would look back at this period of my life with pleasure and gratitude.

Dr Bassam Abu-Hijleh, my supervisor, thank you for your invaluable support, critique and patience during my study.

Dr Ahmad Okeil, Dr Rashed Alshaali, Dr John Smith, Dr Abeer shaheen, My professors, thank you for sharing your vast knowledge and guild line.

My Grand mom, father and mother, I apologize for the time this effort ''stole" from you and thank you for your patients, understanding and encouragement. Thanks you for being always there for me.

Shaahin, we can grow with each other and learn through one another's experiences. We can share the most insignificant and the most shining parts of themselves with the same degree of joy and happiness. Thank you for your unconditional love, patience and continues support.

Dr Nima, Thank u for being always my strength and my best friend. You are Wonderful brother that I can have and I'm proud of being your sister. …

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Nomenclature

A	Total cross sectional area of conducting surface
Altitude	A solar angle indicates the sun height in the sky
ASHRAE	American society of Heating, Refrigerating and Air conditioning Engineers
c	Specific heat capacity [J/(g °C)]
Conductivity	Heat transfer through direct contact within or between two surfaces with different temperature
CO_2	Carbon dioxide
D	Thickness of the material (m)
GDP	Gross Domestic Product: a measure of a country's economic output
K	Thermal conductivity [W/(m.K)]
Latitude	Location of a place on Earth north or south of the equator
Longitude	Geographic coordinate of a place for east west measurements
m	Mass of the substance acting as the environment in grams (g)
Q	Quantity of heat (J)
RH	Relative Humidity
Rt	Total Thermal resistance [m^2 (K/W)]
R-Value	Measure of thermal resistance of insulation materials [$m^2 \cdot$ (K/W)]
SR	Solar Radiation
Δt	Time duration for heat transferring (s)
ΔT	Temperature difference of conducting surface (°C)
U-Value	Heat Transfer Coefficient [W/(m^2.K)]
x	Thickness of conducting surface

Chapter 1. Introduction

1.1 The World Sustainability Scenario

The human population and worldwide economy is growing continuously. By changing the Technology can assist to extend the planet’s resources more, and make the global sustainable. Sustainability is a well designed connection, which included and adapted ecology and technology. In a sustainable world, there is a balance between the public’s need on nature and nature's capability to meet that need.

Facing a big challenge: ecosystem which they cannot sustain the current levels of economics behavior and material consumption and ecosystem is a biological environment consisting of all the organisms living in a particular area, as well as all the nonliving, physical components of the environment with which the organisms interact, such as air, soil, water, and sunlight. The notion of sustainable development gained popularity with the release of the 1987 report. But one of the main broadly referenced sustainability analysis tools worldwide is footprint approach. Although when a population’s footprint is smaller than available bio capacity it is sustainable.

The average person creates an ecological footprint (EF) several times larger than what the earth can sustain according to a report published by living planet (2006, p.30). Ecological footprint that measures how much water area and lands a human population needs to generate the resources it uses and to absorb its wastes under current technology. Ecological footprints allow people to take individual and cooperative actions in support of a world where humanity lives within the means of one planet.

UAE waste a lot of Energy, According to the Living Planet Report 2006, the UAE has the highest ecological footprint in the world, with UAE residents averaging 11.9 global hectares per person. According to the Ecological footprint of Nations 2005 report, the UAE has the largest per capital ecological deficits (negative ecological balances).

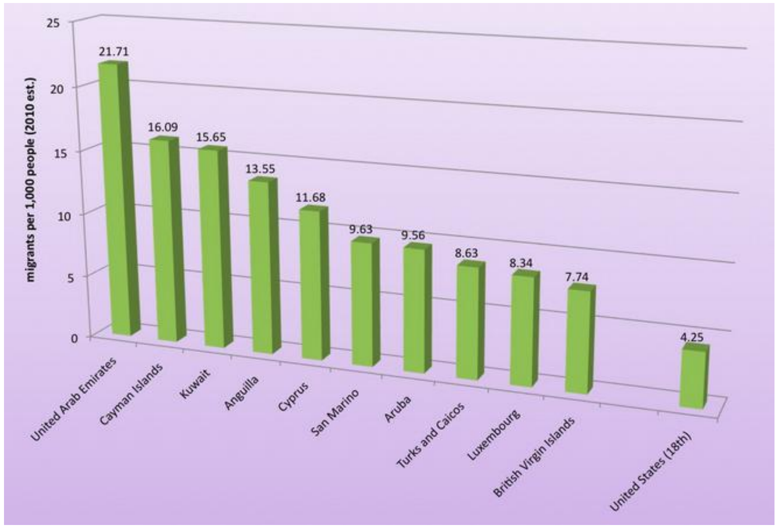


Figure 1.1, Ecological Footprint by Person/per country 2010
Source (http://rankingamerica.files.wordpress.com/2010/06/migration-xlsx.jpg)

Architects and designers bear important responsibilities toward the built environment by adhering to social, cultural and climatic identities and therefore able to achieve a significant footprint reduction without compromising quality of life. Two concepts, Sustainable Housing "need" and housing "demands", are fundamental to an understanding of why, how and in what form sustainable housing development takes place. It's important to establish at the outset how these concepts impact on the volume of housing production, the tenure of new development, its location and the type of dwellings that are built.

1.2 The UAE (United Arab Emirates) Sustainability Scenario

In contrast to major Western cities where the transition from pre-industrial to industrial to post-industrial status occurred gradually over a period of two centuries. The construction industry and urban development in Dubai has flourished in recent years with several of new building that have been added annually (Fig 1.2). **This growth has been extremely fast lately causing environmental issues such as increased pollution, increased energy consumption, compromised air quality, increased human health and reduced natural resources concerns therefore deteriorating the overall environmental ecosystem.**

Figure 1.2, Top view of Sheikh Zayed Road
Source (Personal Archive)

As it's mentioned previously according to the Living Planet Report 2006, the UAE has the highest ecological footprint in the world, footprint is the measurement to everything we consumed and used, including the energy to power all homes. In fact it is our total impact on planet earth.

UAE residents have averaging 11.9 global hectares per person. Which are six times higher than the world average bio capacity per person, and 14 times higher than the carrying capacity per person that is only 0.8 global hectors. The water withdrawal in the UAE is 1533% of total resources. Highest portion of the ecological footprint per person is from the CO2 emissions from fossil fuel, this CO2 footprint was the fastest growing component, and it can be emitted into atmosphere faster than it is removed or observed by the ecosystem within the countries own border. The ecological footprint on nation 2005 update states that the total EF of UAE person is 232.43 while the biological capacity is 19.43 with negative balance equals to -213.43 following figure (Fig 1.3) shows that UAE is located the top counties in term of CO2 emission with relation to the income per person indicator (GDP per capital).

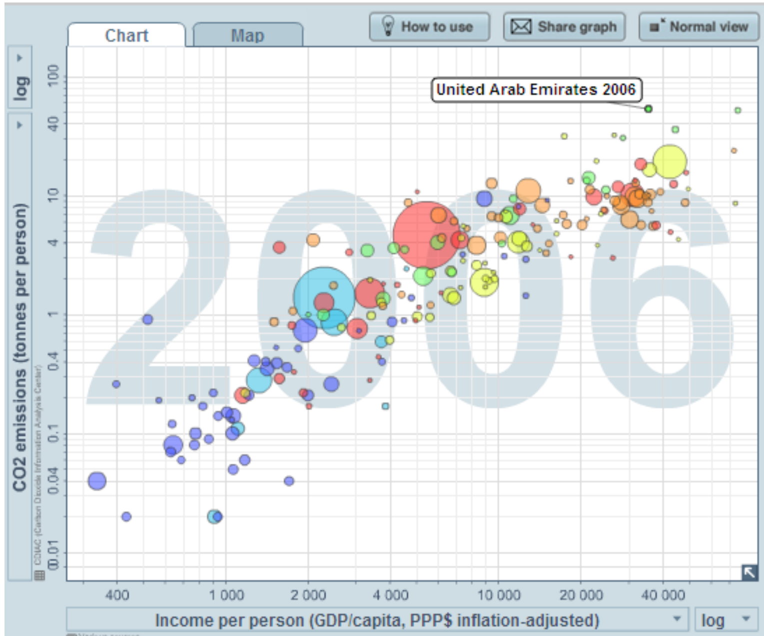


Figure 1.3, CO2 emission with relation to the income per person indicator
Source (http://graphs.gapminder.org/)

The National Human Resources Development (Tanmia) has projected that the UAE population rise in 7.5 million in 2010. This is shown that the population increased 1.9 million from 2006. It added that the UAE population doubles every 8.7 years compared to 55 years for world population average. Houses are alone responsible for 57% of UAE's footprint, if everyone on the planet lived and consumed the same that we do, we would need 4.5 planet earth, but we only have one and we are repeating this resourcing as an ultimate rate. The population growth has added more demands on the housing zone, so selection made in the housing, such as a material contribute radically to the energy consumption. Yesterday's solutions are today's problems, when we consider today's "housing problems" in UAE; it is too easy to forget that they are the result of many years of "housing development".

All of the above raise the need to apply protective measure such as green buildings and more environmentally considerate life style. Green building brings together a vast array of practices and techniques to reduce and ultimately eliminate the impacts of new buildings on the environment and human health. It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic techniques and using plants and trees through green roofs, rain gardens, and for reduction of rainwater run-off.

According to Gulf news (3 October 2009) Dubai Municipality has decided to approve the optional implementation of green roofs in residential buildings in Dubai. The municipality had launched the initiative in line with a law on green buildings to reduce carbon emissions and enhancing indoor environment. The project aims to transform roofs of all buildings in Dubai into cultivated space and increases life expectancy of the buildings, as well as protecting the local eco system. Increased productivity is also expected. Economic support from different sectors is predicted.

1.3 Green Roof

Green roofs are still often seen as a pure aesthetical element in architecture, it's shown as "greenies". A green roof is a roof of a building that is covered with vegetation and soil, planted over a waterproof membrane. Green Roofs are used to grow garden plants, to reduce heating and cooling costs in the building, to increase the roof life span, and to reduce storm water run-off. These roofs also help to filter pollutants and $CO2$ out of the air, insulate the building from sound, help combat the urban heat island effect, and to provide habitat for birds and other urban wildlife. The construction of green roofs on the building have the most advanced in urban planning of the cities, Importance of using clean energy on the environment, which helps the residence for long life. According to green roofs website, industry support different studies have been shown that: On April 2000, City of Tokyo planned that the buildings more than 1000 square meter area must used 20% green space. Also green roof considered in North America like Chicago, Portland, Oregon, and Toronto, which was effective on a building and environment. Therefore, in Vancouver, by increasing the population, instability in energy consumption and waste areas will be increased however; by having the green roof technology can solves these issues. The green roofs have benefits from the thermal point of view. By reducing thermal fluctuation on the outer surface of the roof and by increasing their thermal capacity, they contribute, to the cooling of the spaces below the roof during the summer and to the increase of their heat during the winter, for decreasing the thermal losses, the green roofs save the energy consumption and shading from the plants. Since over the time, they believed that green roofs could absorb the noise. Residence of green roof will investigate from this technology and continued protection of human life and environment. It seems that it is time that the scale of developed city like Dubai must take steps in this direction.

1.4 History of Green Roof

The origins of green roofs began thousands of years ago. In Northern Europe, buildings with green, sloping sod roofs have existed since the time of the Vikings. Perhaps the most famous "green roof" of all, the first Hanging Gardens of Babylon, was built by King Nebuchadnezzar, the son of King Phraortes in 625-585 B.C, was the first king of Media, He reorganized and modernized the Median Army, then joined with King Nabopolassar of Babylonia.

According to accounts, the gardens were built to cheer up Nebuchadnezzar's homesick wife, Amytis. Amytis, daughter of the king of the Medes, was married to Nebuchadnezzar to create an alliance between the nations. The land she came from, though, was green, rugged and mountainous, and she found the flat, sun-baked terrain of Mesopotamia depressing. The king decided to recreate her homeland by building an artificial mountain with rooftop gardens. (Aami, Hanging Gardens of Babylon, 2009)

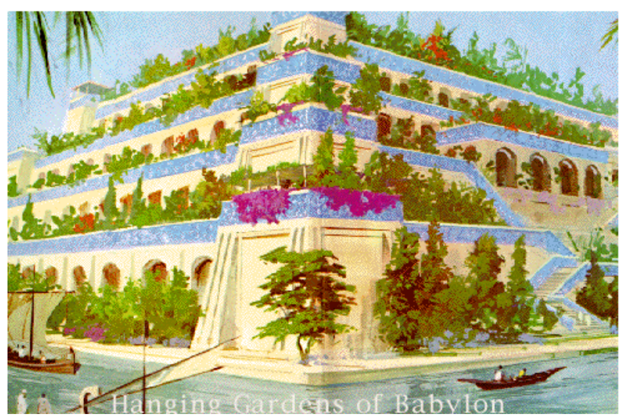



Figure 1.4, 1.5, Hanging Gardens of Babylon, Source (http://nikadon.com/hanging-gardens-of-babylon/)

Many people have asked the question, how the Gardens hanged Well, they didn't! The Hanging Gardens probably did not really hang in the sense of being suspended from cables or ropes. It has different meaning which in the case of a terrace or balcony.

The Tower of Babel of the highest signs of human architecture that has seven large towers with walls of bright tiles and the height of each tower was 200 meters. Near the magnificent Tower of Babel, Palace King of Babylon was built with yellow brick walls and paved floor with the stone sculptures carved in the form of lion. City Hanging Gardens of Babylon was built in the same distances from the castles, which was shown the wonders of the universe and are considered architectural masterpieces. This 5 story terrace gardens that were consistent order another king of Babylon for his wife semiramis were built along the Euphrates River.

Ancient Greek historians, Strabo and Philo, described the hanging gardens of Babylon as follows: "The Hanging Garden has plants cultivated above ground level, and the roots of the trees are embedded in an upper terrace rather than in the earth. The whole mass is supported on stone columns. Streams of water emerging from elevated sources flow down sloping channels. These waters irrigate the whole garden saturating the roots of plants and keeping the whole area moist. Hence the grass is permanently green and the leaves of trees grow firmly attached to supple branches. This is a work of art of royal luxury and its most striking feature is that the labor of cultivation is suspended above the heads of the spectators’’. (Clint Patterson Green Roofs are a Great Idea)

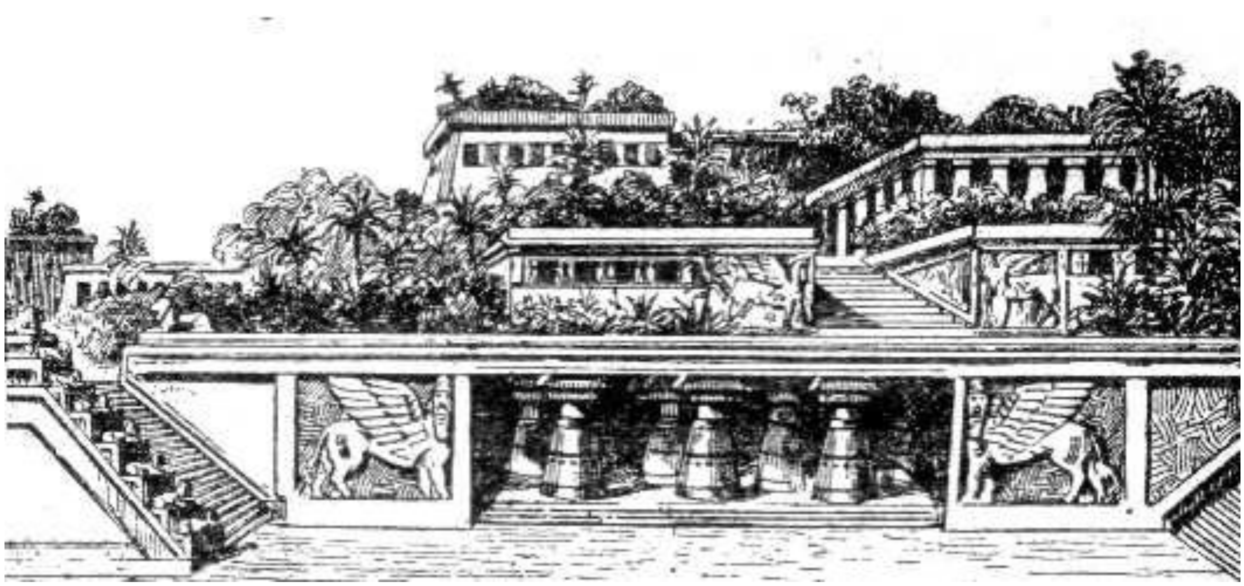


Figure 1.6, The Hanging Gardens, a twentieth century interpretation
Source (http://www.newworldencyclopedia.org/entry/Hanging_Gardens_of_Babylon)

1.5 Definition of Green Roof

Green roof or planted bio roof is a light weight system which allows the plants growths and the same time make possible to protect the roof. Green roof is not just green covered surface but it has a different layer of soil that will be describe in materials section. Sometimes covered protective root with the drainage layer, which is under it and allow species plant grown easily. Usually sedum extensive vegetation is selected for the roof, as the name suggests, Sedum Matting gains most of its low maintenance and can adapts well to poor soil and exposed sites making it a great alternative to grass.

When talking about green roof, green roofs divided to types:

1. Extensive green roof
2. Intensive green roof

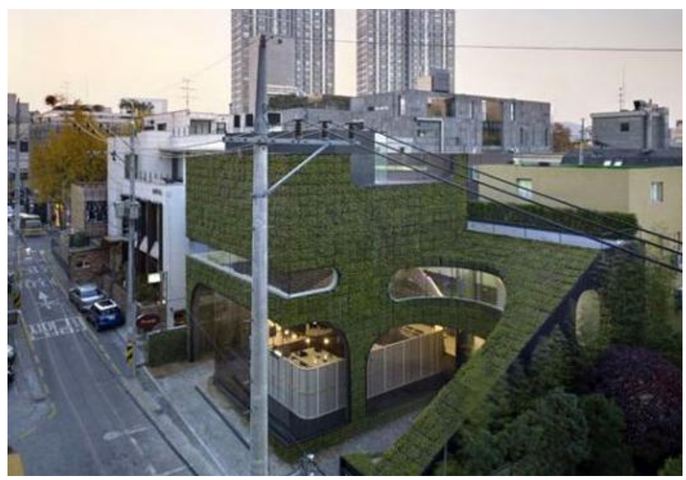


Figure 1.7, 1.8, Different view of Foliage Covered Botanical Building by Mass Studies
Source (http://inhabitat.com/foliage-covered-building-in-seoul-by-mass-studies-architects/)

Use of vegetation on the roof is not a new system. Green roof is a technique of construction and tradition in many years and it has developed in today's cities. The difference between a new green roof and a traditional grass green roof is in the material, which are used and different goals. The main goal of the grass in the past, which is often, took the place to remove the insulation and sealing layer of the birch bar.

1.6 Modern Green Roofs

Modern green roofs are made of a system of layers placed over the roof to support soil medium and vegetation. Until the mid twenty century, green roofs were viewed mainly important aspect of sustainability. However in the 1960's, rising concerns about the effect of urban environment and improve the healthy environment for the residence green roofs becomes as a "green solution" in Northern Europe. So, for this matter new technical research have been studies on root repelling agents, membranes, drainage, and light weight growing media, to plant suitability. Therefore, two modern architects advocates of green roof technology which were:

1. Le Corbusier
   He was thinking to encourage rooftops as another location can be for urban green space
2. Frank Lloyd Wright
   He used green roofs as a tool to integrate the buildings with the landscape, and the same time he aware of environmental and economic impact

According to the design guidelines for green roof In Germany, the green roof expanded in the 1980's. So the other European states have adopted. Now days several cities now incorporate roof greening into regulations and most of the European municipalities currently provide incentives or requirements for green roof installation. The issues which all they motivator for this support has been the public benefits of storm water runoff reduction, air and water quality improvements. And finally the new sectors in green roof construction have become a common feature in the urban landscape. Green roofs are also becoming increasingly popular in the United States, although they are not as common as in Europe. In Canada and the United States which are at least ten years behind Europeans countries in investing in green roof infrastructure as a viable option for solving many quality of life challenges facing our cities. During the early 1990's several large European green roof manufacturers started to venture into the North American markets.

Finally, in Today's life, the green roof technologies have obtained a completely different recognition, owing to successful design and planning. The modern world views Green Roofs to be a healthy environmental idea towards urban design management.

1.7 Types of Green Roof

Green Roofs usually is used for saving energy and decreased the urban areas and improve the urban environment, and generally as it's mentioned previously is divided into two types. Following tables shows the description of each types and finding the advantages and disadvantages of each.

1. Extensive Green Roof
    - Require 1 to 5 inches (less than 15 cm) deep soil and basically plants having a shallow root and is typically look like meadow
    - This type of roof will add loads about 15 Ibs/sq ft to 80 Ibs/sq ft to the roof
    - Extensive green roof costs about 12 dollars for a square feet, which is, includes all required insulation materials and moisture scheme to various plants. (*Greg Zimmerman, 2008)*
    - The types of plants suitable for extensive landscaping are those native mainly from locations with dry and semi dry grass conditions or with rocky surfaces, such as an Alpine environment
    - Minimum soil depths range between 2 inches - 3 inches, which is sufficient to support the smaller plant communities
    - Extensive green roofs can be constructed on roofs with slopes up to 33%, and can be retrofitted onto existing structures with little, or most often, no additional structural support
    - Extensive green roofs are less costly due to single or double layer construction

Figure 1.9, Whistler Daycare Centre: Extensive green roofs are ideal for schools, industrial parks, large big-box stores and multi-family housing, Source (http://commons.bcit.ca/greenroof/faq.html#6)

Table 2.1, Advantages of extensive green roof, Source (www.greenroof.com)

Advantages of extensive green roof	• Its looks more natural • Less costly • Low maintenance and long life • Less technical expertise needed • It is very suitable for large areas • Often suitable for retrofit projects • Dutiable for roofs with 0 - 30° (slope) • Can leave vegetation to grow spontaneously • Often no need for irrigation and specialized drainage systems • Lightweight; the roof generally doesn't require reinforcement • Easier for planning authority to demand as a condition of planning approvals

Table 2.2, Disadvantages of extensive green roof, Source (www.greenroof.com)

Disadvantages of extensive green roof	• More limited choice of plants • Unattractive to some, especially in winter • Usually no access for recreation or other uses • Less energy efficiency and storm water retention benefits

2. Intensive Green Roof
    - Intensive green roofs have a greater need for design expertise and much greater plant diversity
    - Planting media for this kind of roofs have a foot deep which is very minimum, and saturated weights ranging which is depends on type and depth of planting medium and type of the plant are from 80 to 120 pounds per square foot
    - Usually used for new construction, intensive green roofs can be anything from a public garden to an entire park as is the case with the world's largest green roof, Millennium Park in Chicago, which is 24.5 acres of landscaping on top of two subterranean parking garages (www.greenroof.com)
    - Intensive green roofs have a flat roof surfaces which is 1% - 1.5% and the slope percentages can be 3%
    - Different types of plants such as shrubs and trees and different types of depth will be used
    - Soil depths will start at 6 inches - 8 inches
    - Depending on each plant which is used for the roof will received different number of watering for irrigation
    - More expensive, because of different layer which is used
    - The maintenance requirements will also be much greater

Figure 1.10, Top view of Millennium Park In Chicago, Source (http://blog.newsok.com/okccentral/2009/03/20/mayor-micks-dream-park/)

Table 2.3, Advantages of intensive green roof, Source (www.greenroof.com)

Advantages of intensive green roof	• Longer membrane life • Good insulation properties • Can be made very attractive visually • Greater diversity of plants and habitats • Can simulate a wildlife garden on the ground • More energy efficiency and storm water retention capability • Often accessible, with more diverse utilization of the roof. For example, for recreation, growing food, as open space

Table 2.4, Disadvantages of intensive green roof, Source (www.greenroof.com)

Disadvantages of intensive green roof	• Greater weight loading on roof • Higher capital and maintenance costs • More complex systems and expertise • Need for irrigation and drainage systems requiring energy, water, materials

There is also another type, which can use for green roof, which is called Semi intensive green goofs (hybrid). This type is combinations of both extensive and intensive green roofs and is typically adopted to harness both the environmental benefits of a green roof, as well as a diverse garden within a manageable maintenance budget.

Figure 1.11, Vancouver Public Library: Semi-intensive green roofs are ideal for long-term care facilities, daycare play spaces, employee picnic areas, and urban agriculture, Source (http://commons.bcit.ca/greenroof/faq.html#6)

1.8 Green Roof Benefits

Green roof has so many benefits that are divided in to two parts. Following tables describe each part.

1. Private benefits
    - Economy and Energy saving
    - Increase roof life roof membrane
    - Sound insulation
    - Recreational space
    - Food production

2. Public benefits
    - Urban heat island
    - Environment
    - Aesthetics
    - Leed

Table 2.5, Table of description of Economy and energy saving

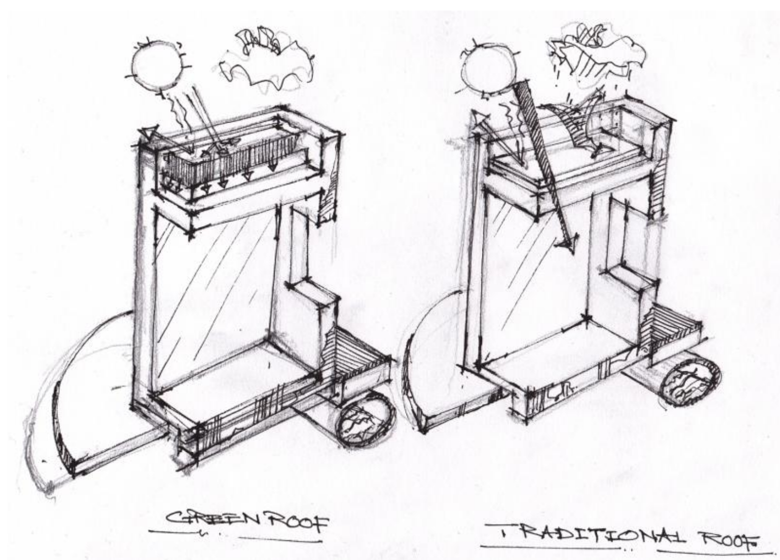
Private benefits	Economy and energy saving
Description	Green roofs reduce the surface temperature of a roof by minimizing heat absorbing surfaces, a green roof helps to reduce energy costs inside the building as well. In summer, the green roof protects the building from direct solar heat. In winter, the green roof minimizes heat loss through added insulation on the roof. Energy conservation translates into fewer greenhouse gas emissions.
Image	 Figure 1.12, Sun Radiation Affect Green roof, Source (Personal Sketch)

Table 2.6, Table of description of Increased Roof life (2-3 folds) Roof membrane

Private benefits	Increased Roof life (2-3 folds) Roof membrane
Description	A green roof helps to protect roof membranes from extreme temperature fluctuations and the negative impact of ultraviolet radiation. A TectaGreen, green roof can double the life span of a conventional roof. With proper maintenance you can protect your investment and prolonging the life of your roof.

Table 2.7, Table of description of Sound Insulation

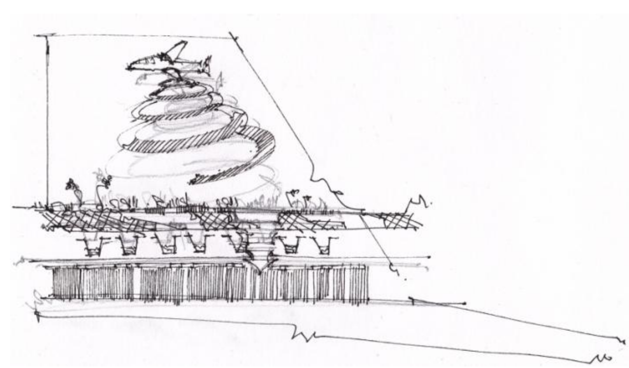
Private benefits	Sound Insulation
Description	Roof covered with the soil and vegetable can be sound insulation and it can reduce the noise.
Image	 Figure 1.13, Sound Insulation, Green roof, Source (Personal Sketch)

Table 2.8, Table of description of Recreational Spaces

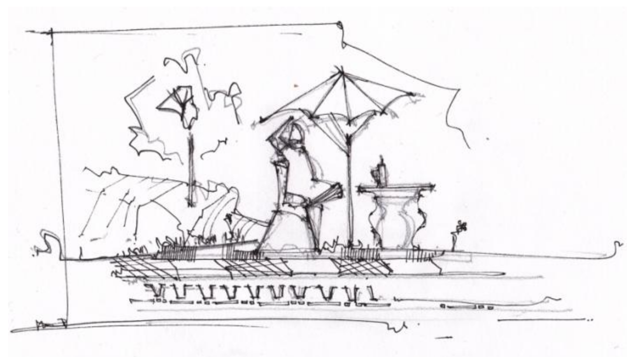
Private benefits	Recreational Spaces
Description	A green roof space for recreation and natural beauty and it's the place for living and gathering.
Image	 Figure 1.14, Recreational Space, Green roof, Source (Personal Sketch)

Table 2.9, Table of description of Food Production

Private benefits	Food Production
Description	A well-designed green roof with plants can be traditional common vegetable. For example: one hotel in Vancouver, Canada produces all the vegetables on rooftop, which is needed for their kitchen, and will save 30,000 Dollar.

Table 2.10, Table of description of Urban Heat Island

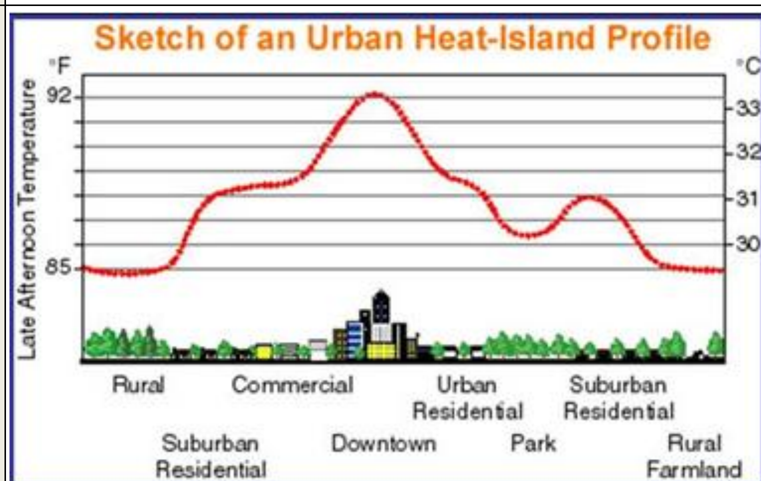
Public benefits	Urban Heat Island
Description	The urban heat island is the overheating of urban and suburban areas, relative to the surrounding countryside, due to increased paved, built-over, and hard surface areas. The urban heat island effect increases the use of more electricity for air conditioners and it increases the rate at which chemical processes generate pollutants such as ground level ozone. Green roof heat island effect by increasing the vegetation was added to the landscape city fights. Also green roofs intercept the solar radiation that would strike dark roof surfaces and be converted into heat thereby improving energy conservation. Like urban forests and reflective roofing surfaces they absorb and/or deflect solar radiation so that it does not produce heat.
Image	 Figure 1.15, Temperatures in the urban core can be 3^{o}-5^{o} C warmer than rural and suburban areas, Source (Lawrence Berkeley National Laboratory)

Table 2.11, Table of description of Environment

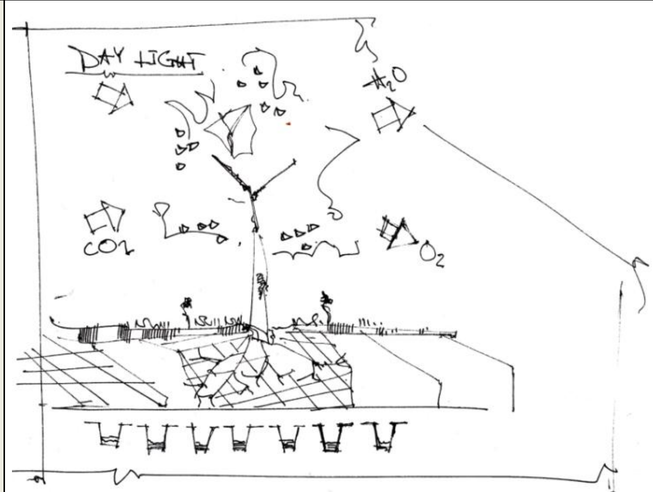
Public benefits	Environment
Description	Energy saving, its means green roof is having the ability to reduce low temperature heat in cities around the summer months will reduce electricity demand. During the winter months the green roof can decrease insulation and provide heat energy demand. Protection of sewage, sewage water pollution is a serious issue. 75% green roof will received an inch perception of the rain. Green roof systems will reduce the waste and swage water.
Image	 Figure 1.16, Green roof can create a beneficial microclimate within their immediate areas, Source (Personal Sketch)

Table 2.12, Table of description of Aesthetics

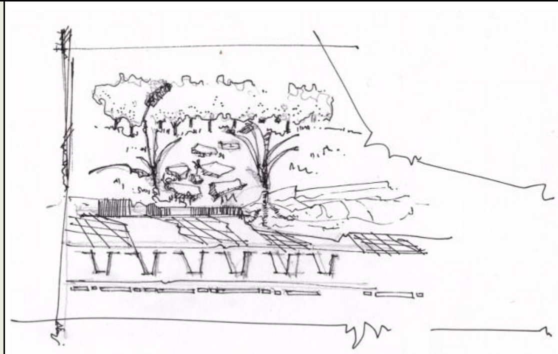
Public benefits	Aesthetics
Description	By creating a functional and aesthetic environment, all TectaGreen, green roofs provide visual appeal. However, an intensive green roof system, trees and shrubs can be included as well as other larger plants in a wider variety. This green space is often an inviting and well-utilized area providing a green respite in an urban setting.
Image	 Figure 1.17, Aesthetics, Green roof, Source (Personal Sketch)

Table 2.13, Table of description of Leed

Private benefits	Leed
Description	By protecting roof membranes from extreme temperature fluctuations and ultraviolet radiation, a TectaGreen™ green roof can double the life span of a conventional roof, and provide energy savings by reducing heating and cooling costs. TectaGreen can also improve site utilization by reducing the impervious surface area of a building to increase potential square footage for construction. And, because TectaGreen conforms to the rigorous Green Building Rating System standards created by the U.S. Green Building Council there are inherent savings including Leadership in Energy and Environmental Design (LEED) certification for tax benefits. The LEED program was created to provide a national standard for the building industry.

1.9 Designing the Green Roof

Since it is necessary to think about the designing of the green roof, the first thing will be considering are the poor physical conditions at the building construction site building and green roof. While it's important to know how the project or a completely new building are suitable or how the old buildings are re-constructed again. So, in this case so many situations will be considered for the customers. Following items shows what to consider before installing a green roof system:

Climate: local climatic factors such as sunlight, wind, temperature and shade, need to consider before building a green roof. Plants can struggle in windy climate or extreme climate. By considering all these factors plant will growth immediately however without considering these issues it becomes big problem.

Direction: North and South side of the roof has a different condition such as light and heat. Also, some part of the roof in the shade of trees or other buildings, the vegetation will grow differently. There are also places, which will receive more water on the roof from adjacent buildings.

Weight: Weight is a concern when installing a green roof. The information should be providing before installed the additional load bearing structure on green roof. A thin green roof weighing will have 50 kg/m when the water is saturated. Lighter samples such s wool will also be available. One layer with wool Instead of a layer with the layer of soil can carry weighing 35 kg/m. Compared with this; the mosaic has a weight of about 33 kg-37 kg. If snow is expected in the area of snow weight must also be added to it.

Slope: Roofs with more than 30 degrees slope do not work well for green roofs. They suffer from slippage and slumping of materials as well as swift release of runoff water. However, 1 - 30 degrees slope is suitable for prevent soil erosion and will lead to stabilize the soil; flat roofs are not always the best for green roofs either. The poor drainage can be damage the flat surfaces and plants. In some countries such as Switzerland green roofs can be located in 60 degrees from the horizontal however; it should be aware climate for installing the roof.

The plants with drought resistant need very good drainage or else they can drown in puddles. The higher slope needs more care that should be taken. Also it should be aware of the plants, which are located on the top, because they are the most droughts tolerant because they will get less water.

Figure 1.18, The green roof onTom Balderston's home studio office has a slope of 6.5:12. The slope of this roof posed some challenges for the Northwest Eco Building Guild design team in 2003. Those problems were solved by using circular drainage units, Source (http://www.pomegranate.org/wp-content/publications/Pomegrante-Center-Greenroof-Manual-2005.pdf)

1.10 Materials

Waterproofing Material: By having the waterproofing material on the rood can protect the roof from water. Waterproofing layer material can protect the structure before destroyed.

Stabilizer Roots: Different countries have different roles and different ways to built green roof, however, some countries don't. Stabilization in Germany will applied under the layer of roofing. Because the roots can't hurt the ceiling layer, stabilizer root also helps the drainage layer. This layer origin may have a chemical and toxic to plants and this will make from a thin layer of copper or synthetic rubber, which doesn't have any hole. For having the green roof and consideration ecological and sustainable architecture it's better to consult with relevant contractor.

Drainage Materials: The main reason for using drainage layer is beneath the soil layer. This work is very important when a dry climate and steep roof regarding the roof in time. Absolutely not necessary drainage operation carried out by a separate layer. Use a soil layer that enough is drained excess water to be able through it's effectively be drainage is common. It's better to used recycled material for this purpose. The simplest materials of natural drainage sand - gravel which are natural and the same time low cost.

Wool Stone: The roof vegetation roots can penetrate and the friction between layers of wool and bitumen roofs cause the place to be installed. Wool can greatly to keep the water in a longer period for the plants.

Material Foam: These materials will the drainage the water however a lot of water and nutrients will not maintain.

Sheets of Plastic cups (tiny hole): Some of these materials used for extensive green roof which have a few centimeter thicknesses of soil and some of them used for intensive green roof which have thicker layer of soil. The idea of the overflow of the water in the cup is the same in the roof. Compared with wool that where the gravitational water to the edge of roof and pull crown of roof would be stayed dry. The advantage of this material are designing and relocating. And the disadvantage of this material is very dry. Another disadvantage of the plastic is it's none renewable resources. In addition to specific characteristics of drainage materials, cost, access, weight, insulation cost, etc … can be different after the selection.

Layer to Prevent Erosion and filter: A layer to form a fiber coating in order to stabilize performance drainage mat is installed above the drainage layer. When it's buying the Sodom the mat layer in available and it's shown as the three-dimensional network of plastic, which is, helps to control the soil erosion layer and keep the following layer in place. A use layer to prevent erosion of the slope depends on the roof.

Fire Resistant Material: Any soil can' be used as roofing. Soil consists of coal (peat) or with organic organisms (microbial) functionality and reduce the dangerous fire on contraction.

Plant Species and Stabilize: It is essential that appropriated plants be selected in every climate, where its terms periodically very dry, too hot, too cold or too humid. The most important issue in the roof is wide range of vegetation resistance. A few species suitable for green roof is Sodom with the different colors and different growth patterns. This with combination of most common moss plant, which is used in roofing, is widespread. Therefore, planting different plant species will be implemented in two ways:

1. Use pre prepared by mat
2. Construction of green roofs by planting sprouts and transplant

1.11 Details of Green Roof

Green roofs for are used in long-term forecasts; in fact, green roofs have doubled survival in comparison with conventional and conventional roofs. Following figure shows the details regarding the green roof; a layer of rubber or plastic that is in flat roof is traditional. Below the plastic layer insulation the material such as per-lit is located and the insulation of drainage layer on the top is added (Fig 1.19).

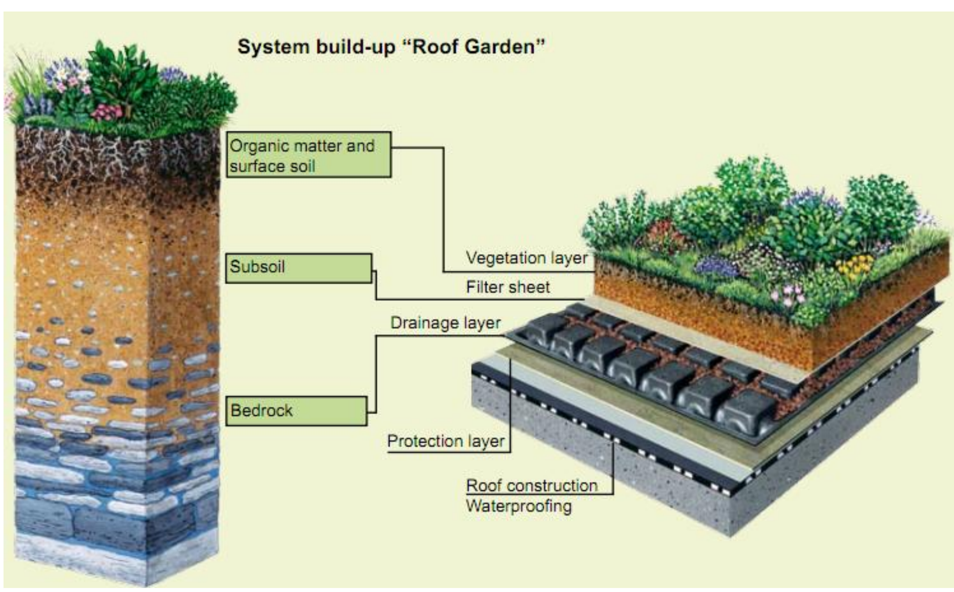


Figure 1.19, Detail of Green Roof, Source (http://www.zinco-greenroof.com/EN/downloads/pdfs/Green_Roof_System_Solutions.pdf)

The detailed shows that green roof in the bottom has the structure to retain the necessary quantities of water to support the plants, whilst draining off the excess. The plant type, geographical region and the roof itself determine the required amount of water. Apart from creating the correct green roof system to support the plants, it is very important to protect the waterproofing from both mechanical damage and attack from plant roots.

1.12 The Role of Green Roof in Sustainable Architecture and Urbanism

Green Roofs will effect on heat island also reduce waste to provide a healthy environment and human health in long time measurement. Generally, dark roofs will absorb more heat; however, the roof, which is covered with the different kind of plants, will greatly reduce the temperature. The dangerous part is sewage pollution, which is included the heavy metal materials from the roof and mosaic surfaces into waterways. Green roofs can easily absorb the negative impact. Toady's architects and engineers dealing with sustainable buildings, and new approaches are called green roof (Eco-Efficient green roof, 2011). Following items shows the effect of green roof in architecture and urban:

1. Cooling Effect: green roof have so many methods to reduce energy saving of the building, basically reduce the hot in summer. The roofs, which are covered with the layer of soil and different kind of plants, will have more shade on the surface rather than surroundings. Therefore, soil and plants with evaporation cooling effect of moist air had makes breathing easier.

2. Insulation and reduce the cold winds of winter: layer of soil can act as additional insulation in winter. However, different thickness of the soil can control the heats of the building in wintertime.

3. Increase roof life expectancy: green roof can protect the roof from the shell. For example, covered the roof with a pitch has about 25 year's life expectancy. Because its ultra violet rays are the levels and then makes the brittle expansion and contraction by thermal fluctuation and case more gap in the form of shell so its need to be replaced. Thus, green roofs also protect the covered layer of ultra violet rays and extreme increase in temperature, so this will increase the roof life expectancy. So, materials and energy will be saved and less waste it will produce.

4. Solar Frames: Building construction projects will select the level to frame the roof as the solar and energy protection and is installation of green roof surface in this case it will have more harmony with the environment. In fact, it would be useful of biodiversity through the production of light and shade with solar paneling to create a microclimate of the mosaic. On the other hand, solar paneling has on the lower ambient temperature compared to the covered black pitch roof with vegetation around.

5. Recycled materials and transportation: a wide range of materials offered by contractors to install green roof which are such as:

    - Chemicals: including pesticides or any substance will be an exposed root. Whether a proposal is in harmony with the environment?
    - Material recycled: drainage materials from renewable sources or recycled material?
    - Plastic: plastic is a bad habits for invertebrates and there is no potential to preserve nutrients. Also plastic is a source of renewable energy production and it's a large consumption.
    - Transportation: what distance for green roof layers and other material should be over?
    - Herbs: Are there any native plants or species are imported?

    These considerations against the heavy weight and costs, warranty, and incentive projects, maintenance and non-weight roof are compared to accommodate an appropriate combination of environment, which is more efficient selection.

6. Structure: there is a range of techniques are developed for modern green roof, including drainage material - under the layer (large amount of soil) selected types of plants species and the method which is constructed. For each project of green roof there is a different condition of site. And the goals and objectives will be consider on choosing the material and construction methods. Therefore, if planning to built a green roof it should carefully consider the following two parts:
    - Know what you want and what features?
    - You get better result

7. Aesthetic: the primarily constructed of green roof can be aesthetic and this function generally does not conflict with the functions of green roofs.

8. Welfare: broadcasting health and welfare of the value of a green roof are directly related to the selected material, which is used.

9. Ecology Biodiversity and the Environment: Population effects of the consumer with the installation of specially designed of the green roof biological and will affect the environment. In this case by selecting and considering the right material such as natural or recycled and choosing the native species or at least proportional to the ecosystem would be conceivable.

1.13 Disadvantage of Green Roof

The green roof has an environmentally beneficial for all kind of climate, but installing and maintaining one is fraught with disadvantages.

Table 2.14, Table of description of Disadvantage of green roof

Green roof disadvantages	Description
Cost	Expensive and the cost are depending on what kind of green roof it is used, so, the maintenance could be higher and some types of green roofs do have more demanding structural standards. It’s obviously known that the designed and installed waterproofing system and root barriers can increase the initial cost of the roof
Dead load	Because of the dead load the substrate and vegetation loading some existing buildings cannot be retrofitted with green roof and this will increase the construction

1.14 Summary of Green Roofs Benefits Finding

The previous studies conducted on the green roof have been presented in the literature review. Basically green roofs are engineer vegetarian roof cover with plants and growing media or the engineer soil taking the place of regular concrete tile or the single roof. All roofs are designed of wet water and keep the building dry right? But green roofs are different the most important aspect is that they are living in grading roofs planted with many types of vegetation. Green roofs have been around very forms since a fable hanging garden of Babylon to Scandinavians side's homes to the elaborate rocker brothers set to the roof gardens felt in 1930. The roof place of modern green roof technologies Germany, where the engineer systems were developed and have been testing for over 35 years, and where there is a lot of government support too. So imagine the design liked layer system of material covering the roof. Engineer to keep the roof water type and create an environment to plants survives. Here are few presented material section for typical convectional or built in place green roofs. These are complete system for ones shopping where the companies are offer warranties but you can also costume design one too specifies the individual components. The number of wares and the placement barriers system to system and green roof type but at the early east all green roofs include the single to multiply water proofing layer, drainage, fabric, growing media or the engineer soil and the most exiting site plants.

Another way to create green roof is with the modular system that are individual trade's sets side by side on top of the water type roof. Another modular option to planting the roof is to use very lightweight tin nuts that are fully vegetated with no magnate sedum and miasmas. They are arrived holed up and in stacked on sites. There are advantages to all types of system hybrid and custom designs and in terms of design there are two main types of green roof:

Extensive and intensive, the entire green roofs are open design for future or both. Also called eco roofs, extensive roofs are thinner, lighter and less expensive. There are used for primary design this for ecological roof cover with no or limited human access. Extensive grown of plants must be high heat, dry, wind and fast tolerant. So, for generate the nature and overall had low maintains requirements. Typical plants are alp gram covers like supplants and some flowering orbs called scrapes and muses. Media depth range from 1 inch up to around 6 inches and saturated rate started about 75 pound per square foot. Generally it said that green roof can be installing on slopes up to about 30 degrees, all over the yard green roofs are much higher patches. Intensive green roof on the other hand are more indecent and latch and much heavier and deeper, they look more like a tradition roof garden because there are built on military flat roofs and much wider plants can be used like vegetables garden and trees. Architectural ascents like waterfalls, plants and sort of recreational are possible with an intensive green roof system and of course the initial cost and maintenance requirement will be higher. Green roof have development and medicate the negative impacts of a building footprint by someone recreated the lost green face at roof level.

Green roof are use storm water management at act like punches by absorbing green water slowing and cooling the down as well realizing the cleaning run off. They create the healthy environment by filtering air and binding dust particles absorbing CO2 and lowering ambient temperature which then lower urban heat island effect with living breathing plants through photosynthesis and vapor transpiration. Since green roof are covered with engineer so and fans they keep area under them cooling in summer and warmer in the winter with reducing cooling and energy consumption and cost. And because materials are buried the green roofs protest the structural elements from UV-ray-radiation, wind and temperature which its terms house double, triple or more the life for the roof so maintenance and the avoidance cost are also avoided. Another major benefit is those planted roofs which introduce floor in to the concrete jumbo and it’s financing and habituated area for this place and in dangers birds another wide life. They also provided cons equation and noise pressure and even reduce glare.

Also think of a marketing and good real opportunity for companies and government leaves the ways he glares for his design and very importantly green roof creates new real state by taking advantage of usually forgot and unused top façade of the building its roof.

However, the previous studies fell short of assessing these environmental aspects on the green roof in hot and humid region such as Dubai. There are no sufficient studies to test the climatic efficiency of such proposals. Those findings of literature review will be incorporated in the suggested model, and appropriate selected methods or design will be applied in the hot and humid climate context.

Chapter 2. Literature Review

2.1 Factors Affecting the Cooling Performance of Green Roofs

Green roofs can be act as passive cooling the buildings and their surroundings. Green roofs have the potential to improve the thermal performance of a roofing system through shading, evapotranspiration, better insulation values, and also reducing a building's energy demand for space cooling (Liu, Chicago, 2003). So by evaluating the factor such as climate of the location and the plants and thickness of the soil can reduce the Surface temperature.

Green roof planting designers must be considering multiply criteria such as:

1. The clients need and their budget
2. Access and safety issues
3. Location; micro and micro environment, humidity or dryness, maximum and minimum temperature
4. Weight and depth
5. Irrigation

2.2 Climate

In order to estimate the role of the climate in the cooling performance of green roofs, a comparison has been made. In different hot and humid with specific ambient air temperatures countries the mean surface temperatures of green roofs are compared with the surface temperatures of concrete.

Following graph shows the results of temperature measurements in different cities of hot and humid region in summer daytime:

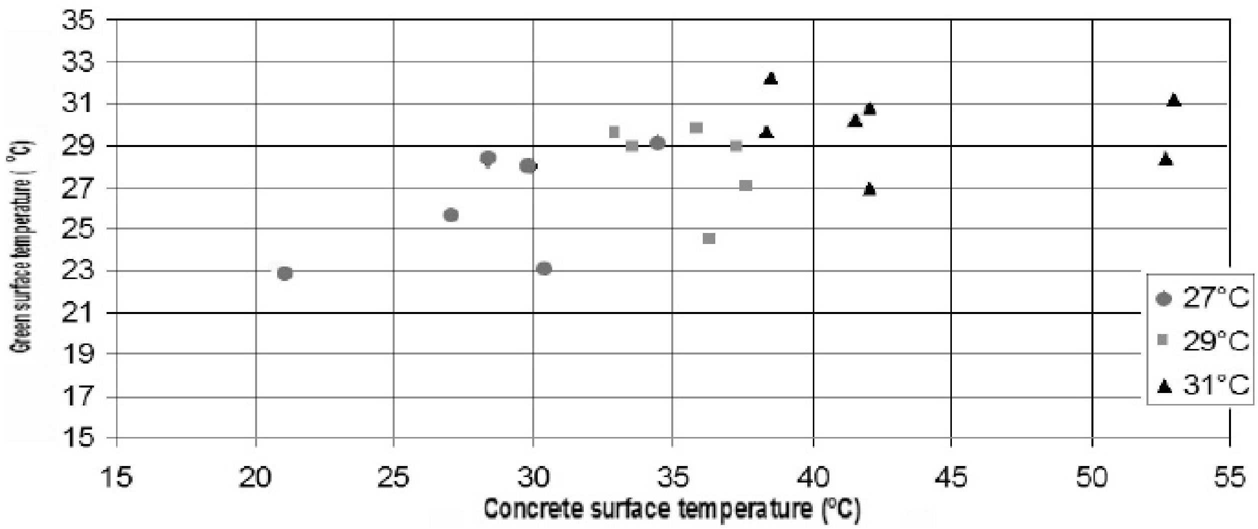


Figure 2.1, Shows the results of temperature measurements that took place in various cities with hot and humid summer. Daytime (7:00-20:00), Source (Kleanthi Kanellopoulou)

From these figure shows that the green roof surface temperature range of fluctuation is much smaller than the concrete roof (Kleanthi Kanellopoulou, 2008. Oxford). Following table shows the difference temperature of different surfaces:

Table 2.1, Difference temperature of different surfaces, Source (Kleanthi Kanellopoulou, 2008. Oxford)

Type of the surfaces	Temperature (°C)
Concrete	21°C – 53°C
Green roof	22.9°C – 32.2°C

Following graph shows the results of temperature measurements that took place in different cities with hot and humid summer Nighttime:

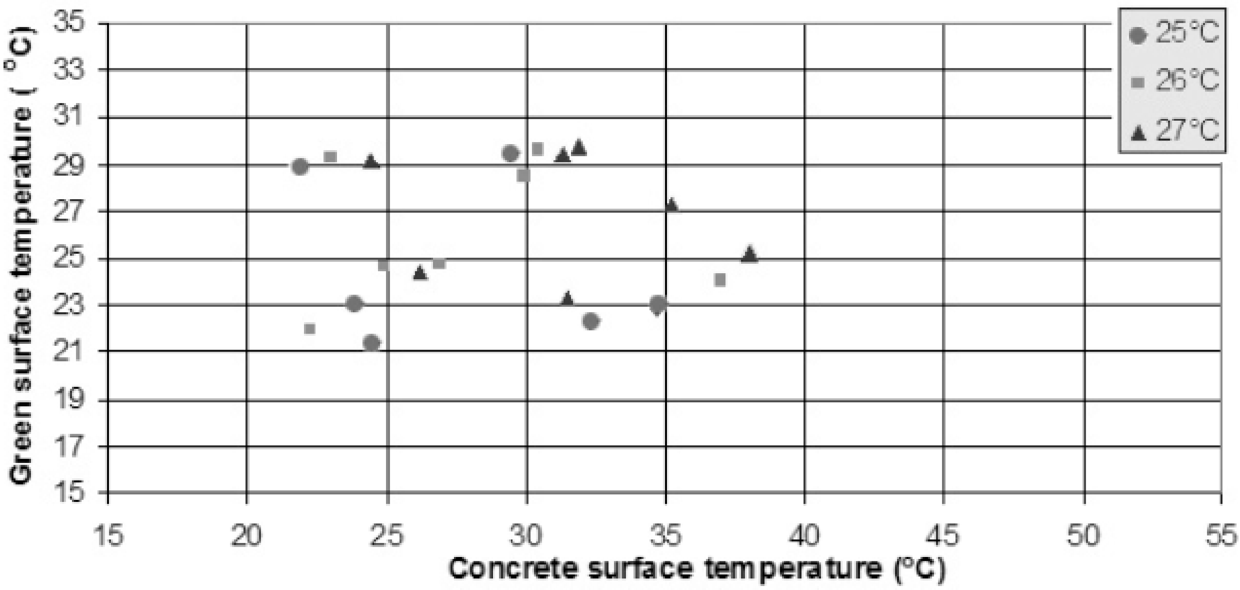
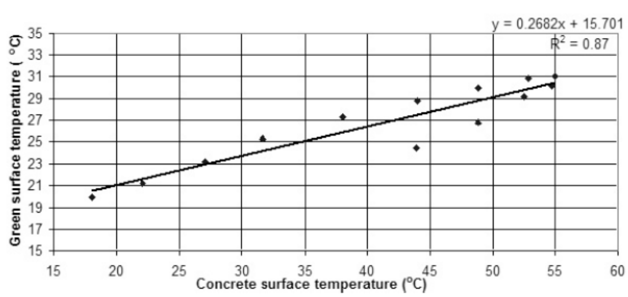


Figure 2.2, Comparison of green roofs' surface temperatures against concrete roofs' Nighttime (20:00-7:00), Source (Kleanthi Kanellopoulou)

From this figure shows that the green roof surface temperature fluctuation is almost the same for the green roofs at night, but for the concrete roofs is dramatically reduced. Without solar radiation the temperatures at the concrete roof considerably decrease at night, whereas for the green roof remain at the same levels as daytime's (Kleanthi Kanellopoulou, 2008. Oxford).

Following graph shows the results of temperature measurements that took place in different cities with hot and dry summer daytime:



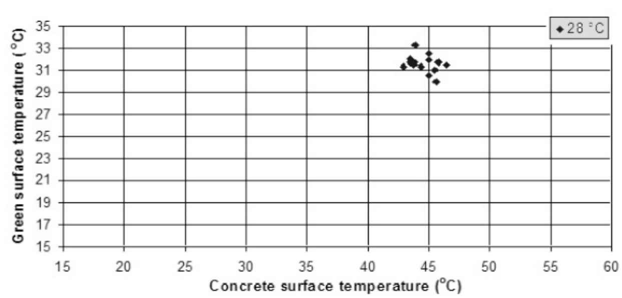


Figure 2.3, Comparison of green roof's surface temperatures against concrete's in Athens, Source (Kleanthi Kanellopoulou)
Figure 2.4, Comparison of green roof's surface temperatures against concrete's in Greece, Source (Kleanthi Kanellopoulou)

The result and simulation have been studied in two different cities. The first one is Athens and the second one is Greece. From each graphs shows that the temperature range of the green and the concrete roof is different.

The range of fluctuation of green roofs' surface temperatures is almost the same as in the hot and humid climate and much smaller than the one of concrete roofs (Kleanthi Kanellopoulou, 2008. Oxford). Following tables shows the temperature of each surface:

Table 2.2, Difference temperature of different surfaces, Source (Kleanthi Kanellopoulou, 2008. Oxford)

Location	Concrete surface temperature (°C)	Green roof surface temperature (°C)
Athens	18°C - 55°C	20°C - 31°C
Greece	43°C - 46.4°C	30°C - 33.3°C

After analyzing the climate of hot and humid and hot and dry it's shown that the climate does not have an important impact on the planted roofs performance.

In this study also by using the plant such as Leaf Area Index (LAI) can reduce the green roofs surface temperatures. Therefore, these plants will bring the effective shading on the roof. On the other hand the thickness of the soil can affect on thermal performance of the building in hot and dry and hot and humid climate.

2.3 Thermal Analyze Studied

2.3.1 Plants in Green Roof

Vegetation has an important impact on the thermal performance of buildings in summer and winter. Temperature decreases due to different vegetation and is primarily affected by the vegetation itself. Plants absorb some of solar radiation for their growth and biological functions, functioning as a solar barrier that prevents solar radiation absorption extensively (Wong, 2002, Australia). Vegetation it's basically placed on roofs and walls, which can be considered as urban greens. Also it's providing visual enhancement, air and noise control, this natural solution also contributes to the thermal benefits on a building and surrounding environments (Wong 2002 Cited Singapore, p.261-270).

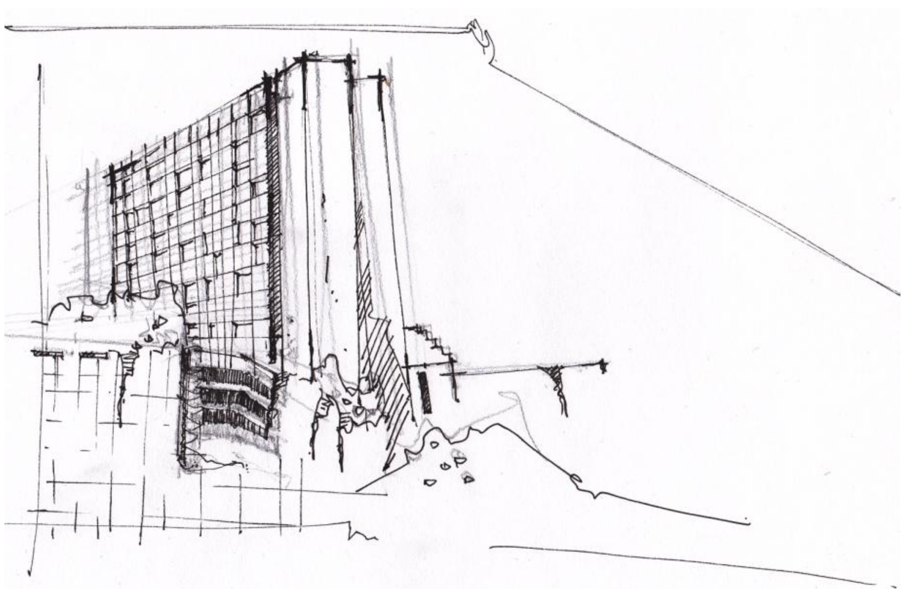


Figure 2.5, Rooftop gardens in Singapore commercial building, Source (Personal Sketch. Wong 2002, Singapore)

It is observed that temperature will be decreased around 30°C with the shading of different plants. So, green roofs contribute thermal benefits to the buildings and their surrounding environment (Wong 2002 cited Singapore, p. 261-270). Among to the substrates, the best thermal reduction is burned sludge which is reduced the 88.8% rooftop surface and 75.3% under the roof slab surface (Yi-Jiung Lin, 2011, Taiwan p. 345-355). Also an examination of physical properties shows that burned sludge has the highest porosity, and its abundant air provides great heat insulation (Yang KH, 2007). Burned sludge can be reduced the rooftop surface temperature from 6.5°C to 7.7°C with or without irrigation, and the thermal reduction percentages of heat amplitude were from 87.0% to 90.4%. Burned sludge substrates reduced temperature differences on the rooftop surface from 32.2°C (bare roof) to 4.2°C (roof with greenery) with or without irrigation. (Yi-Jiung Lin, 2011, Taiwan p. 345-355).

After analyzing the differences of temperature on the surface area of the building with green roof or without green roof it's shown that sand can reduce the temperature on the rooftop surface from 5.9°C to 7.1°C. Also, sand is a good substrate for crassulacean acid metabolism (CAM) plants. Following table shows the experimental data on four different substrates:

Table 2.3, Experimental data on four different substrates, Source (Yi-Jiung Lin, 2011, Taiwan p. 345-355)

Material	Porosity (%)	Water Holding capacity (%)	Dry weight (kg/ m3)	Wet weight (kg/m3)
Sand	3.1	29.2	1605.6	1997.6
Sand with Charcoal	6.9	31.2	1468.5	1780.5
Man Mixed	12.7	52.3	469.6	992.6
Burned sludge	37.8	32.3	830.5	1153.5

The studied, which is done for the burned sludge and sand is shown that, these are not only saves the water resource for irrigation, but also solves the increasingly serious problem of reservoir sedimentation in hot and humid region.

2.3.2 Thickness of the Soil

The benefit of green roof is to reduce the heat into the building. Green roof can reduce the cost of the building and energy (Wong 2002, P. 353-364). Wong defines the parametric factor that deal with thermal transfer from the green roof, the concept of the roof thermal transfer value (RTTV) takes into consideration three basic elements of heat gain:

1. Heat conduction through opaque roof
2. Heat conduction through skylight
3. Solar radiation through skylight

And for calculating the maximum permissible RTTV the following formula will be used: (Wong 2002)

Peak RTTV = Peak sensible cooling for roof component / Area of roof

Different vegetation (low, medium and high), different thickness and different R-value reduce the thermal performance of the building has been summarized in following table:

Table 2.4, Detailed Calculation of R-values of different Soil Thicknesses, Source (Wong 2002)

Soil Thickness (mm)	Clay soil (dry) R-Values (m^2 K/W)	Caly sil (40% moisture content) R-Values (m^2 K/W)
100	2.349	2.012
200	2.749	2.076
300	3.149	2.139
400	3.549	2.202
500	3.949	2.266
600	4.349	2.329
700	4.749	2.392
800	5.149	2.455
900	5.549	2.519

So, studies all above will shown that the maximum saving 1% - 3% on the annual energy consumption, 2% - 64% on the space cooling load and 2% - 71% on the peak space load could be obtained with different soil thickness of 100mm - 900mm. and the green rooftop garden with shrubs (300 mm thick soil and shrub) could be saved 15% of annual consumption, it's also 79% in space cooling load and in peak space load. From the tables is shown that the clay soil (dry) 900mm thick soil could save 3% in the annual energy consumption, 64% in the space cooling load and 71% in the peak space load (Wong 2002 cited Singapore, p. 261-270).

(Lui and Minor, 2005) has been studied the different of heat transfer between a colored growing medium compared to deep green roof, compared also to a reference roof with the same structure (steel deck with insulation layer above). Thermal performance has been improved by thicker substance. The thicknesses of the soil layers will influenced the thermal diffusivity of the soil. As the density decreased, the thermal conductivity of the soil will be decreased (Del Barrio, 1998). Following figure shows the Comparison of the energetic exchanges of the dry or wet green roof with a traditional roof, summer season:

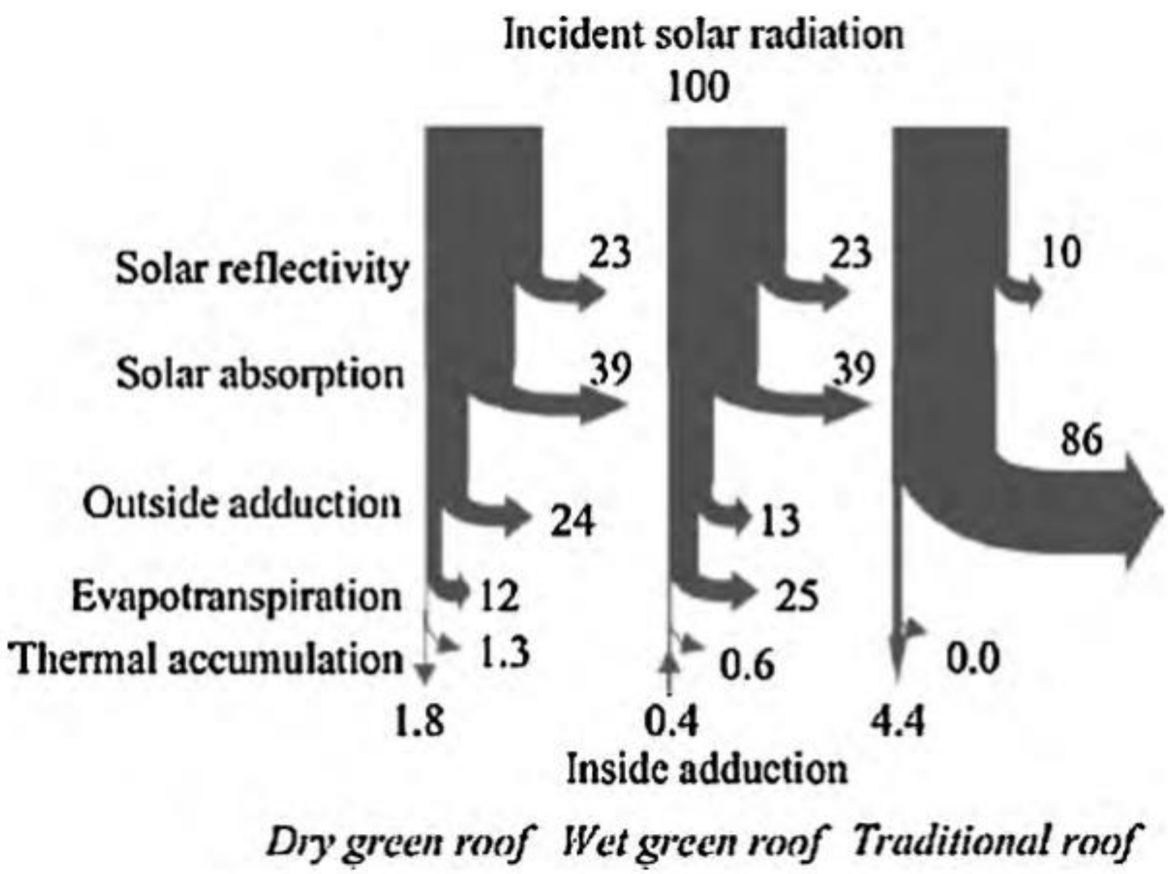


Figure 2.6, Comparison of the energetic exchanges of the dry or wet green roof with a traditional roof, summer season, Source (Lazzarin et al, 2005)

For better reduce heat gain loss into and out to the building is need to have the thicker layer of the soil. Following figure shows the Comparison of measured surface temperature of hard surfaces, soil surface without vegetation cover, and soil surface covered with different kinds of plants:

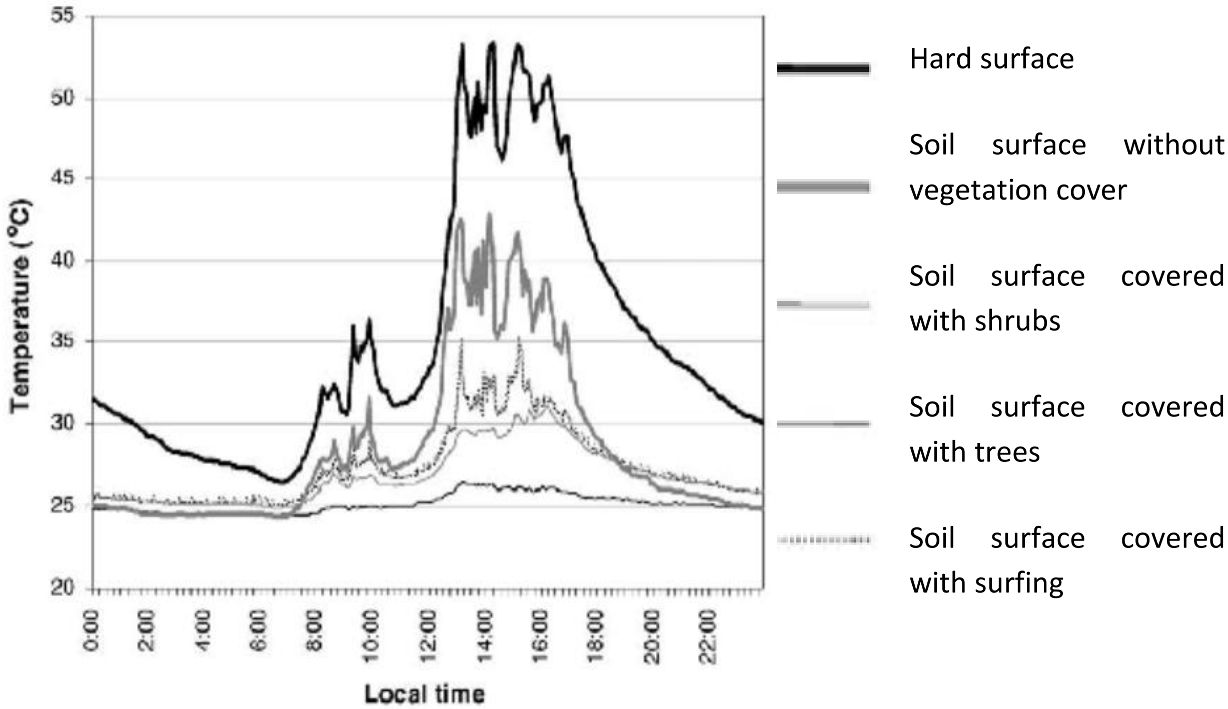


Figure 2.7, Comparison of measured surface temperature of hard surfaces, soil surface without vegetation cover, and soil surface covered with different kinds of plants, Source (N.H. Wong et al./Energy and Buildings 35, 2003)

2.3.3 Thermal Conductivity

Thermal conductivity is the rate of heat flow through the material Perpendicular to the surface of 1sqm area of the material. The unit of measurement is W/ (m.K). Following formula and table shows the way to calculate the conductivity of each material:

$$k = \frac{\Delta Q}{A \times \Delta t} \times \frac{x}{\Delta T}$$

Figure 2.8, Thermal Conductivity Formula, Source (http://en.wikipedia.org/wiki/Thermal_conductivity)

Table 2.5, Thermal Conductivity

Value	Description
K	Thermal conductivity
ΔQ	Quantity of heat
A	Total cross sectional area of conducting surface
Δt	Time duration for heat transferring
ΔT	Temperature difference of conducting surface
x	Thickness of conducting surface

2.3.4 Thermal Resistance (R-Value)

This is the resistance to heat transfer through a material by conduction ($m^2 \cdot K/W$). Following formula and table shows the way to calculate the R-value of each material:

(R) Value = D/K

Table 2.6, R-Value

Value	Description	Unit
R	Thermal resistance	$[(m^2 \cdot K)/W]$
K	Conductivity	[W/(m K)]
D	Thickness of the material	m

2.3.5 Overall Heat Transfer Coefficient (U-Value)

The rate of the heat goes through material called U value with units of W/m2 K. Less heat can grow through the Material with the low U value number, materials with high U-value have low insulative properties, but materials with low U-value have high insulative properties. Also, Humidity affects the absorbtivity of the heat due to the increased conductivity in the material. Some insulation materials do not absorb humidity such as rock or glass; other can store humidity to certain level without losing the insulative capacity such as natural wool and adobe structure (Koch Nielsen, 2002, pp. 105). Following formula and table shows the way to calculate the U-value of each material:

(U) Value = 1/Rt

Table 2.7, U-Value

Value	Description	Unit
U	Heat coefficient flow	[W/ (m^2 K)]
Rt	Total thermal resistance	[W/ (m^2 K)]

2.3.6 Insulation Materials

Different kind of vegetation on green roof can shows the different temperature on surface. Therefore, the conventional roof (roof without green roof) will be depending on the construction material. The lowest temperature of green roof with thick dark green vegetation is between 26°C and 29°C. And the highest temperature of green roof which is covered by sparse red vegetation is between 36°C and 38°C. On the other hand, the insulation material can easily control the climate on the building, and at the same time reduce the energy loads of the building. Insulation can control the heat transfer from outside the building surface into inside the building surface which is also based on conductivity (Koch Nielsen, 2002, pp. 102 & 103).

2.4 Effect of Climbers on Building Temperature

Several studies and papers have been dealing with the effect of strategic landscaping on the thermal performance of a building envelope. As Meier, (famous architect) mentioned that the careful designing of Climbers around the surface of the building can beneficially improve the thermal comfort within the building, also it can help to save energy which is required for air conditioning. Therefore, the cooling effect of daily temperature reduction in the exterior and interior surfaces is very well and reduce the heat flow and it's a good way for energy saving. According to Nigel Dunnett and Noel Kingsbury, the authors of *Planting Green Roofs and Living Walls* (2008), Climbers can reduce the maximum temperature in a building by shading walls and roofs from the radiation of the sun, the daily temperature fluctuation start reducing by 50%, so, this will be the great solution for summer climate. Therefore, for having more effect on building the total area that are shaded is much important than the thickness of climbers. Buildings have been perfectly insulated by shading in each climate, the shading will stop the heat entering into the building and climbers are the most effective ways to reach this stage. For reducing the heat temperature it's better to design the climbers on the wall that face the sun, windows also maybe shaded by climbers. Also, climbers can provide insulation in winter not only by maintaining a pillow of air between the plants and the wall but by reducing wind chill on the wall surface. Also others paper has been described and discussed more about green wall that is shown on Appendices section.

Figure 2.9, Gherkin building goes green, by Jorge Chapa, 04/01/07, Source (http://m.inhabitat.com/gherkin-gets-a-green-roof/)

2.5 Summary of Literature Review Finding

The previous study conducted on the green roof has been presented in literature review. In summary, the different elements have been discussed, and the studies carried out the environmental performance, with respect to the climate. The green roof in one of the several integrated system designed to create a productive and comfortable in work place. While the rooftop soils and grasses insulate the building from the midday sun, a raised floor cooling system allows evening breezes to flush the building at night. The findings are summarized as follow:

Climate: most of the studies about green roof have been related to the hot and humid region as very few literatures were discussing the hot and dry region (Kleanthi Kanellopoulou, 2008. Oxford). The high humidity is a climate, which is in Dubai that can be resolve with similar strategies applied in hot and humid climate, which is basically based on the humidity conditions.

Different vegetation and thickness of the soil: The represented studies were concern the temperature range of the green roof, on the external surface which is depending on the different kind of vegetation and thickness of the soil which is covering every place on the rooftop. And all discussed the effect of different vegetation and soil on the building. Therefore all these will improve the environmental efficiency of the house. Also, it was found that the efficiency of the green roof increase when it’s applied the correct plants and soil on the roof top which also provide the shade. Following items shows the effect of the vegetation and soil on the building:

1. Improve air quality
2. Cooler temperatures and more moisture through the natural evaporation
3. Visible green roof provides a beautiful landscape
4. Reduce the west water
5. Reduce the heating and cooling loads
6. Increased longevity of traditional roofs which are covered with grass
7. Succession of open space where the structure sits

Instruction can be executive in the building and it can be use as clean energy and also be attention to the environment for residence when the sustainable architecture and urban development increased. The temperature of green roof surface depends on different kind of vegetation, which exists in different places. As it's shown in literature review the covered the lowest temperature of green roof with thick dark green vegetation is between 26°C and 29°C. And the highest temperature of green roof which is covered by sparse red vegetation is between 36°C and 38°C. Also the effect of green roof is according to the construction material, which is used in the building. During the summer the external surfaces of insulated green roof are heated less than the traditional flat roofs. Besides, in the summer period the planted roofs reduce the heat losses (Wong 2002 cited Singapore, p. 261-270).

Insulation and shading: the most recommended shape for the hot and humid climate is to have shaded area that means less exposure to the solar radiation. So, the different plants and trees on the rooftop of the building can provide the shade. On the other hand solar radiation and heat will transfer easily from non-insulated surface and have a higher temperature range however; solar radiation and heat can be block with the insulated surface and green roof. Thus, the differences of the thermal conductance coefficients between non-insulated roofs with and without the green roof confirm the contribution of the green roof to the reduction of the heat losses and also its significant thermal performance above non-insulated roofs.

Climbers on the building: Some papers emphasize the importance of effecting the landscape and climbers on the building, which can reduce the thermal load and comfort of the building. So, this including the effect of the different kind of plants that were covered in wall can minimize the surface temperature. (Nigel Dunnett and Noel Kingsbury, the authors of *Planting Green Roofs and Living Walls* (2008)).

However, the previous studies fell short of assessing the effect of green roof on thermal performance of the building. There are no sufficient studies to test the effect of green roof in Dubai. Those finding of literature review will be incorporated in the suggested model, and appropriate selected design method will be applied in the hot and humid climate context.

2.6 Case Study of Green Roof on Different Types of Building

Sustainable design is an approach to architecture that grew in response to the increased environmental awareness of the late twenty century. So many designer and architects design and develop the green roof in different form. In this part of research shows some of them and describe them in different tables.

Table 2.8, Description of green roof on Hill House

Project name	Case Study 1. Hill House
Image of the building	 Figure 2.10, Hill House, Source (http://www.architecture.uwaterloo.ca/faculty_projects/terri/125_W03/Storus-hillhouse.pdf)
Type of the building	House
Location	La Honda, California
Architect	Jersey Devil
Date	1979
Green roof size	2,500 sq.f * 10.76 = 26,900 m²
Soil depth	8 inch * 2.5 = 20.3 cm
Description	1. Sustainable, Building form (organic) 2. Harmony with the environment and roof is continuation of the landscape 3. Local material and recycle, Planted with winter rye, native plants, and wildflowers, the green roof slopes down to join the interior courtyard, which is landscaped with honeysuckle vines and an oak tree

Table 2.9, Description of green roof on Nine House

Project name	Case Study 2. Nine House
Image of the building	 Figure 2.11, Nine House House, Source (http://www.greenroofs.com/projects/pview.php?id=354)
Type of the building	Swiss complex of 9 residential homes
Location	Dietikon, Switzerland
Architect	Peter Vetsch
Date	1993
Green roof size	37,674 sq.f * 10.76 = 405,372 m^2
Soil depth	2.3-6.5 inch * 2.5 = 5.75-16.25 cm
Description	1. To integrate a building into its environment 2. The roof designs of these buildings include sprayed concrete domes 3. Recycled glass insulation foam (25 cm thick) 4. A root resistant Polymer bitumen vapour barrier, geotextile fabric and excavation material 5. Between 40 to 80 cm landfill and humus was derived from the building footprint

Table 2.10, Description of green roof on Clementiwoods Condominium

Project name	Case Study 3. Clementiwoods Condominium (University of Art)
Image of the building	 Figure 2.12, University, Source (http://www.skyrisegreenery.com/index.php/projects/all/)
Type of the building	University of Art Design
Location	Singapore
Architect	Mace Studio
Date	2010
Green roof size	500 m^2
Soil depth	4-6 inch * 2.5 = 10-15 cm
Description	1. Circulate the air around the building which is reduce high temperature 2. Wind control 3. Glass wall used inside the building, which is used for natural lighting of the studios and classrooms 4. Reduce energy 5. Landscaping on rooftop 6. Important component of sustainable urban development

Green buildings have become a new technology for architecture around the world as the idea of environment protection and reduce the footprint has become more and more popularity in society. By understanding and study all these buildings can find that green roof will use in all kind of climates, by having different thickness of the soil and different plants can reach to the best solution of the green roof.

2.7 Aims and Objectives

This Research examines the effect of green roof in thermal performance of the building in hot and humid region. To study of the existing situation and the inference of the results concerning the microclimate of the indoor and outdoor environment of buildings where a green roof has been located. The proposal, which is with references to the literature review, has been finding, and all these will be compared with different model.

The main aims of this research are the following:

1. Assess the suitability and appropriateness of the green roof in hot and humid climate (Dubai)
2. Identify the advantages of the green roof in hot and humid climate (Dubai)
3. Energy Efficiency

The main objectives of this research are the following:

1. Assess the environmental performance of the proposal model using computer simulation such as Ecotect.
    - 1.1. Analyze the weather data
    - 1.2. Solar radiation
2. Estimate the energy consumption (thermal performance, cooling loads) based on following patterns:
    - 2.1. Orientation
    - 2.2. Different Types of the building
    - 2.3. U-value, Soil thickness and Density
    - 2.4. Different type of local plants

These aims and objectives are based on the studies, which have been noted earlier, specifically:

1. Review the green roof history, benefits, types, requirement, designed, material, and also green roof disadvantage.
2. Review the different type of green roof with respect to their climatic performance and efficiency.
3. Apply the best type of green roof in existing residential house in hot and humid region.

2.8 Proposal Description

In this section, two different residential building with different storey's and height shows the different or similarity of different parameters of the building. The selection of midrise building is based on the common practice in Dubai for the midrise housing building, which, range from four to ten levels (Fig 2.13, 2.14).

Figure 2.13, The Greens-Dubai-Nine level, Source (Personal Achieve)
Figure 2.14, **Grand Apartments in Dubai International City** G+10, Source (Personal Achieve)

Therefore, by selecting the midrise building is defined as ‘’moderately high building’’: a building with ground + mezzanine + nine level heights (Fig 2.15).

Figure a,b 2.15, Residential Midrise G+M=10, Two different side of the building, Source (Personal Achieve)

Following Table show the studying of different parameters of existing residential building without green roof:

Table 2.11, studied of each building

Parameter (Fixes)	Number of Storey’s	Total area of the Roof (m^2)	Total Built area (m^2)
Residential Mid Rise	G+M+9	1,917.27 m^2	257,664.53 m^2

On the other hand the selection of villa is based on the common practice in Dubai for the villa housing projects, which range from two levels. Following figures shows the examples of the some residential villas in Dubai (Fig 2.16, 2.17).

Figure 2.16, Shoorooq-Dubai Villa G+1, Source (Personal Achieve)

Figure 2.17, Palm Jumeirah Villa G+1, Source (Personal Achieve)

The villa is defined as ‘’modern building’’: a building with ground + one floor on top (Fig 2.18). This type of villa is common now a day.

Figure a,b 2.18, , Residential Villa G+1, Two different view, Source (Personal Achieve)

Following Table show the studying of different parameters existing Residential villa without green roof:

Table 2.12, studied of each building

Parameter (Fixes)	Number of Storey’s	Total area of the Roof (m^2)	Total Built area (m^2)
Residential Villa	G+1	358 m^2	711 m^2

After analyzing these two types of building, in this part its need to analyze the detail of the roof and the thickness of each layer also it's necessary to know about the conductivity of each materials of the roof. Following figure and table shows the detail of each layer of the roof:

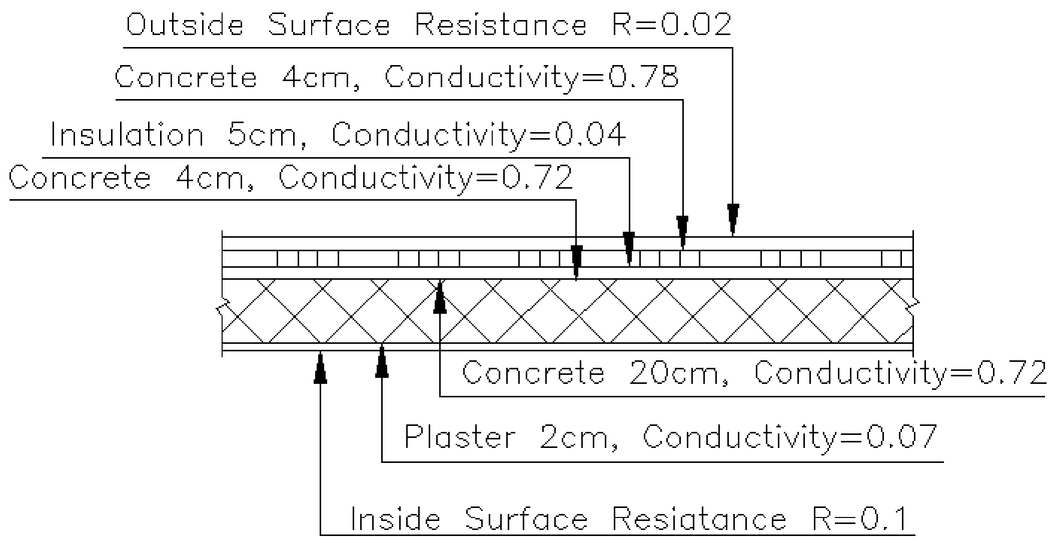


Figure 2.19, Roof Detail (Caad Drawing)

Following Table shows the Detail of roof:

Table 2.13, Detail of Roof

Roof Detail	Thickness (m)	R-Value (m².K/W)	Conductivity (W/m k)
Inside Air Resistance		0.1 m².K/W	
Plaster	2 cm / 100 = 0.02 m		0.07 W/m K
Concrete	20 cm / 100 = 0.2 m		0.72 W/m K
Concrete	4 cm / 100 = 0.04 m		0.72 W/m K
Insulation	5 cm / 100 = 0.05 m		0.04 W/m K
Concrete	4 cm / 100 = 0.04 m		0.78 W/m K
Outside Air Resistance		0.02 m².K/W	

In following chapters the annual total solar radiation, along with other data of the building will be compared in both residential building without green roof. Therefore, the characteristics of the tall building are distinguished from low-rise buildings, which are including high net density (ratio of floor space to area of site) and a building height that extends above the urban canopy. It's very important to know that how much solar radiation will affect on the building thermal performance, then it's very easy to control them (Geiger 1973, p442-447).

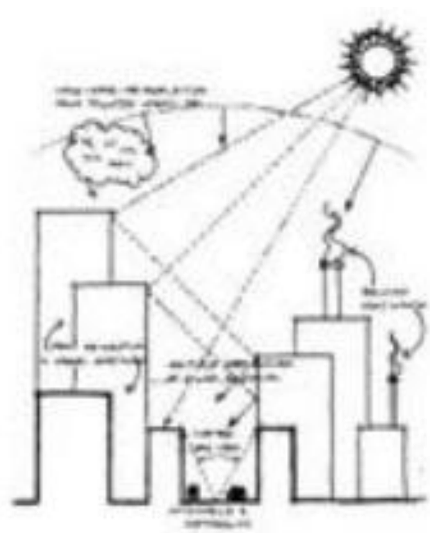


Figure 2.20, The affect of solar radiation on tall building, Source (http://www.peterstclair.com/pdf/The-Climate-of-Tall-Buildings-Science-Review_LR.pdf)

As it's shown on Fig 2.20 the areas of a tall building above the urban canopy layer will receive more solar radiation than below the urban canopy, which may be shaded for portions of the year due to greater exposure and reflections from adjacent rooftops. Additional solar radiation is received by vertical surfaces (facades) in urban areas from low altitude sun in the morning and evening than would be the case in a natural environment. In other hand humidity is influenced by the ground and low level and in a similar way to temperature where evaporation from the ground surface is directed upwards as vapour leading to decreasing humidity with height. Measurements and simulation show that the humidity will be decreases during the day with additional height above the ground and it will be opposite during the night which means that the humidity will increase by the height. Tall buildings such as mid-rise and high building can reduce the wind speed.

Moreover by applying the green roof different variable have been analyzed:
Firstly, Different type of the building, two different residential building with different heights should be simulating. Therefore the height from floor to floor of each building is different. The height of the villa from floor to floor is set to 3.74 m. and totally the height of the building is 8.08 m. and the height of the mid rise residential building from floor to floor is set to 3.60 m except the ground floor which is 5.45 m. and totally the higher height of the building is 4,247.5 m. second, the insulation, roof material thickness, different type of U-value. And the third, different designs of green roof, some types greenery design will be proposed for each roof and simulate each one separately. Then to find out which building which have the highest energy consumption in Dubai climate, and the result will draw the best parameters that can be used in roof form to achieve the best and the highest energy saving in hot and humid climate. Next, by applying and examining the green roof on each and compared in an energy consumption of per square meter, knowing that that the heights and total area of the roof and built area will vary from one variable to another. Again, by designing the different type of green roof can minimize the energy consumption and get more benefit.

For having the green roof in Dubai, can use both extensive green roof or intensive green roof, the key here which has to consider is the system of green roof and the ability which can retain water and prevent waste and over watering. Therefore the planting the green roof is another issues which should be consider. In Dubai, it’s better to use local plants from succulent family in addition there were a handful of grasses that have been successful with. Usually for the thickness of the soil is better to use 10.16 cm - 15.24 cm (4" - 6") for Extensive and intensive green roof. For the watering the green roof is better to use the system which can retain more gallons of water in 1 meter at 10.16 cm (4") depth media which is very successful system for hot and humid climates. The same system also can be used as the base of the common public areas on the ground before it is back filled with media for planting simply to save the water and prevent waste.

Generally the height of the building can effect on green roof, pending the height it’s better to think about the orientation of the building, solar radiation, direction of the wind and the evaporation factors. Finally for the U-value, which is hard to calculate because, there are so many variables for each individual building. However the researches and different papers show that a savings of 40% - 60% on air conditioning in the US is not uncommon much depends on the size of the building. The shading and evapotranspiration are key contributors to the results.

Chapter 3. Methodology

3.1 Alternative Methods Investigation

This chapter shows as a link, to link findings of the literature review and to provide and find the basis and the best methodology for this research. Therefore, different research papers have been discussed and different methods have been choosing the best Approach investigation for applying the green roof on the buildings in different climate such as hot and humid region. However, this project discussed about the effect of green roof on thermal performance of the building in Dubai. In this part there are different methods to complete the investigation, which is suggested in different paper and the same time to explain the reason for selecting them.

- Laboratory Approach
- Modeling Approach
- Experimental Approach
- Simulation Approach

3.1.1 Laboratory Approach

This is the most important method for analyzing the thermal comfort on the building. For analyzing the effect of green roof on thermal performance of the building should evaluate two type of the roof, the first one is conventional roof and the second one green roof. Therefore, for applying the green roof in Dubai is difficult. Because the climate in Dubai which is usually hot and humid. So for avoiding the difference on the mechanism result it's better to work in lab. The accurate result should be according to the condition of the built model.

Furthermore making the scale model of two roofs and studying the size of the building and roof details is needed to study. However, it's a big gap between the sample model and real. So, computerized and simulate through the best software program to avoid the gap. And in this approach need more skill and knowledge and also at the same time its cost a lot and need the accessibility for lab and finally it is time consuming.

3.1.2 Modeling Approach

This method is less costly, and has some more advantages, such as changing the detail of the roof and materials to get the best result. However in this approach can modeling the existing building and change the type of the building, which can get the best result of thermal comfort. Although the physical modeling can create more accurate results that are more close to real condition, this method needs too much time and facilities.

3.1.3 Experimental Approach

In this approach so many papers have been studied to get the best result. Others experiment can help the process to go faster but the same time it's better to get the real building. After using the other simulation can use and compare with computer simulation data, which is shows the measurement and all data on the table or graphs. This approach should be done in long period of time and in different conditions. Different factors can effect, so different factor should be studied. If it's a short-term observation, it can be used as validation for another method on investigation such as simulation approach.

3.1.4 Computer and Simulation Approach

This approach needs the enough knowledge and skills to evaluate and it's not costly. This is the fast practical experiment in different conditions. In this section can study and affect the different parameters, which will effect on building. Also, the inputs of the program should be accurate to get correct results and it's very necessary to validate the program. Also in this part has some mathematical calculation, which is under investigation and should be divided to its components. A mathematical equation should be written for each component and combined together to present an equation for the main element. To have an accurate calculation all the parameters, which affects the result, should be considered in writing the equations. And effect of each parameter should be investigated separately.

3.2 Description of the Investigation Method, which will be used

There have been no methods to just identify specifically the effect of green roof on thermal performance of the building. As discussed in chapter 2, effect of green roof in general is a topic that mainly lies within building and urban environment. And it's not just focusing on the thermal performance of the building. Consequently, the evaluation approach should be based on one of the evaluation approaches within the building and energy and by using different simulations can get the best result. Nevertheless, as is discussed at the end of chapter 2, the main aim of this research, computer simulation and technology assisted evaluation methods should be integrated into energy and thermal performance of the building rather than urban environment. In this research needs to compare two roofs; conventional roof and the other green roof, and see the effect of green roof on thermal performance of the building in Dubai. First, it's very important to analyze the weather data of United Arab Emirates (Dubai). Second, investigate two type of the roof for each building. Also all details and material of the roofs should be collected and studied. Third, basic model of these selected roof should be making in software and analyze. So, for getting the best result is better to use simulation program. This is relatively fast and requires enough knowledge and skill on using the program. The idea of this to collect some data by experimental and observation and do the simulation of different condition in the same climate and compare the results.

3.3 Research Methodology: Computer Simulation

Analyzing the thermal performance of the building can be done with two parts. The first one can be as computer simulation and experimental measurements, which are, conducted in outdoors and indoors temperature and solar radiation where the green roof has been placed, then the study of green roof thermal performance using simulation method. There are variable software tools that can simulate the method applications.

Therefore, the computer simulation method is used within the designers such as architects and engineers in every level, especially in concept, which can easily test the building in different climate and see the effect. The simulation has benefits for all designers because they can evaluate the multiple design alternatives in the concept and if didn't work they can easily change the design. Moreover, the simulation program can be very good for sustainable architecture; through the simulation can deliver the more energy efficiency in to the buildings.

One of these simulation tools is virtual environment (VE), by Integrated Environmental Solution (IES). It can cover and analyze the climate at both local level and within the global level and bringing relevant characteristics to the surface for evaluation and to inform design strategy. ASHRAE / Koeppen Geiger climate classification, temperature, humidity, moisture, solar energy, diurnal swing, wind, precipitation and etc…

On the other hand the basic experimental measurements that can be used a camera of infrared thermograph. Unfortunately, the unaided human eye cannot see in the infrared. This measurement tool used for the measuring the outdoor, indoor temperature and relative humidity in both out and inside surfaces. By measuring these can study the thermal comfort of the building. However, Infrared thermograph is a very cost effective tool that enhances the building industry. The accessibility of this tool is not easy and this also needs to test in the reality and its take so long.

This research is conducted using another simulation tool, which is Ecotect by Autodesk '' sustainable analyze tool that delivers a wide range of simulation and analysis functionality through desktop and web service platforms''.

Ecotect is quite different from other analysis tools in that it specifically targets the earliest stages of design. Ecotect is a studio companion which designers can have a better understanding of the relationship between buildings and surround such as environment. As visualization tool Ecotect interactively displays sun and shadows, solar rays, sun path diagrams and etc… As an analysis program there are 3 common methods for calculating and visualizing data:

- Analysis Grid (of points)
- Analysis Surfaces
- Thermal Analysis of Zones

Fundamentally, there are five main reasons to consider ECOTECT as part of your analysis workflow:

3.3.1 Modeling and Visualization

For the conceptual modeling the most complex building geometry Ecotect is the best and fast software, which can be used. However the model in Ecotect is editable and the other thing such as inclining walls, rearranging zones, manipulating complex curves, moving apertures or even adding and deleting surfaces are all straight forward and its shows as a bottom all around the software. To assist in the design process, it easy to set the Sun path diagrams, shadow information, lighting grids or simply move the model around in real time, month and year. With this result which is shown through analysis directly within the context of the building model, safe in the knowledge that the client will understand that they are looking at preliminary ideas and not the finished product.

3.3.2 One Central Repository for all Building Data

In Ecotect each material can store and shows the wide range of information including basic thermal and surface properties, acoustic response, detailed layer descriptions and environmental impact data if it is loaded. Therefore, it's easy to assign complex annual operational schedules and hourly profiles for controlling occupancy, appliances or internal conditions**.**

3.3.3 Internal Analysis Functions

Ecotect can analyze the internal function that can be easily used at any time while making the modeling. These provide feedback on parameters such as sun penetration, thermal performance, internal light levels, potential solar gains, and reverberation times. Also it can use generative functions in any design, allowing the design to automatically shape shading devices given specific performance parameters or even interactively spraying acoustic rays to accurately position reflectors. So, all these analysis functions in Ecotect it's automatically calculate and simulate the volumes and internal surface areas for each zone.

3.3.4 Import and Export Capabilities

After drawing the model in Ecotect it's easily can export to other analysis tools including Energy Plus and Radiance. This will help to embed all the design information and the building data into a single model file which can be used as the basis for a whole suite of more focused lighting and thermal analysis. By analyzing the results and editing building geometry, can have the perfect tool for iteratively generating and optimizing solutions for a range of design problems.

3.3.5 Energy Plus

Different input will give different result of analyzing; however, there are many aspects of a building model that are common to all tools. By understanding of modeling in Ecotect it's easy to analyze the performance, and its help a very quick to pick up. Obviously there will be some differences between model in Ecotect and model in energy plus will accept, however, these are all checked and explained whenever its export.

3.4 Simulation Process

After understanding the software and find the best one for simulating in this section, the simulation which has done with software will be explained in details until the result which is given for analyzing. Field investigation with weather tool instrument is another research method, which has been used in this research. Other investigation method is computer simulating and calculations, which is the quantitative method and the purpose is to reach to a deeper understanding and description of a subject. And at the same time literature review on chapter 2, was an alternative and useful method to collect and understand other papers Ideas on the same subject and getting the idea from them and finally getting the best results.

Moreover, the most important method is to investigate is the computer simulation. Since there is no way to examine on the existing building and at the same time there is not enough time and limited budget to examine the different situations on the roof so, computer simulation is more accrue and reasonable to use. Thus, computer simulation highly controls different conditions and situations, and provides reliability and repeatability.

3.5 Climate in Dubai, United Arab Emirates

Location: the United Arab Emirates

The United Arab Emirates is located in the Middle East region of Asia. It is at the tip of the Arabian Peninsula, having borders with Saudi Arabia and Oman and is one of the GCC (Gulf Co-operation Council) States. It consists of seven emirates, which include Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah, and Fujairah. It contains 200 islands, covers an area of 83,600 square kilometers (32,400 square miles) and is located at 23° 49 North, 54° 20 East.

Figure 3.1, The United Arab Emirates Map, Source (http://guide.theemiratesnetwork.com/maps/uae_world.php)

Dubai is one of the seven emirates of the United Arab Emirates (UAE). It is located south of the Persian Gulf on the Arabian Peninsula and is roughly at sea level (16m/52 ft above). The emirate of Dubai shares borders with Abu Dhabi in the south, Sharjah in the northeast, and the Sultanate of Oman in the southeast.

3.5.1 Climate: Hot and Humid

Dubai weather is generally hot and humid with a high daily average of sun hours. And the hottest months are July and August.

Hot and Humid Region is as follows:

1. Little rain full, falling mainly in winter (November to March)
2. Hot and humid in the summer, temperatures range from 10º C to 48º C.
3. Mild in the winter and there are occasional sandstorms
4. High intensity of direct solar radiation
5. Low thermal fluctuations between day and night

According to climate of Dubai (Wikipedia 2010), the climate of Dubai has a hot arid climate. Summers in Dubai are extremely hot, windy and dry, with an average high around 40 °C (104 °F) and overnight lows around 30 °C (86 °F). The highest recorded temperature in Dubai is 49 °C (120 °F). Most days are sunny throughout the year. Winters are cool and short with an average high of 23 °C (73 °F) and overnight lows of 14 °C (57 °F). Precipitation, however, has been increasing in the last few decades with accumulated rain reaching 150 mm (5.91 in) per year. The climate of Dubai is an arid subtropical climate because of its location within the Northern desert belt.

The weather in Dubai can bring short and irregular rainfall as is typical for the Middle East. Most of the rainfall in Dubai occurs between December, January, February and March. The weather between December and March remains cool and is considered as most comfortable climatic conditions throughout the year.

Table 3.1, Monthly weather data for Dubai, source (http://en.wikipedia.org/wiki/Climate_of_Dubai)

Climate data for Dubai													[hide]
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	31 (88)	31 (88)	41 (106)	41 (106)	45 (113)	45 (113)	47 (117)	48 (118)	43 (109)	40 (104)	41 (106)	31 (88)	48 (118)
Average high °C (°F)	24.0 (75.2)	25.4 (77.7)	28.2 (82.8)	32.9 (91.2)	37.6 (99.7)	39.5 (103.1)	40.8 (105.4)	41.3 (106.3)	38.9 (102)	35.4 (95.7)	30.5 (86.9)	26.2 (79.2)	33.4 (92.1)
Daily mean °C (°F)	19 (66)	20 (68)	22.5 (72.5)	26 (79)	30.5 (86.9)	33 (91)	34.5 (94.1)	35.5 (95.9)	32.5 (90.5)	29 (84)	24.5 (76.1)	21 (70)	27.5 (81.5)
Average low °C (°F)	14.3 (57.7)	15.4 (59.7)	17.6 (63.7)	20.8 (69.4)	24.6 (76.3)	27.2 (81)	29.9 (85.8)	30.2 (86.4)	27.5 (81.5)	23.9 (75)	19.9 (67.8)	16.3 (61.3)	22.3 (72.1)
Record low °C (°F)	8 (46)	7 (45)	11 (52)	8 (46)	17 (63)	22 (72)	25 (77)	25 (77)	22 (72)	16 (61)	13 (55)	10 (50)	7 (45)
Precipitation mm (inches)	15.6 (0.614)	25.0 (0.984)	21.0 (0.827)	7.0 (0.276)	0.4 (0.016)	0.0 (0)	0.8 (0.031)	0.0 (0)	0.0 (0)	1.2 (0.047)	2.7 (0.106)	14.9 (0.587)	88.6 (3.488)
Avg. precipitation days	5	7	6	3	0	0	1	0	0	0	1	5	28
Source #1: Dubai Meteorological Office[5]													
Source #2: Qwikcast [6]													

Solar Radiation

After examine the sun chart diagram for this villa, the optimum orientation can be figured out in regards to solar radiation. The simple and the best orientation of the building is where the short facades of the building face east and west. The best orientation is North West –East South 190 degree.

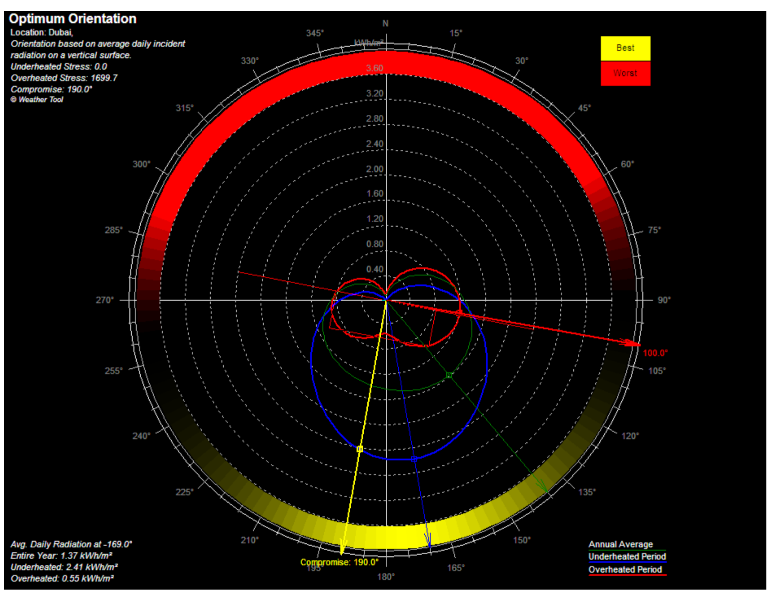


Figure3.2, Best orientation of the building, Source (Ectect)

Solar Radiation

The following graph shows the optimum orientation, the solar radiation can be decreased during the warmer months (when the excess heat is not needed) and increased for the colder months when the heat is needed.

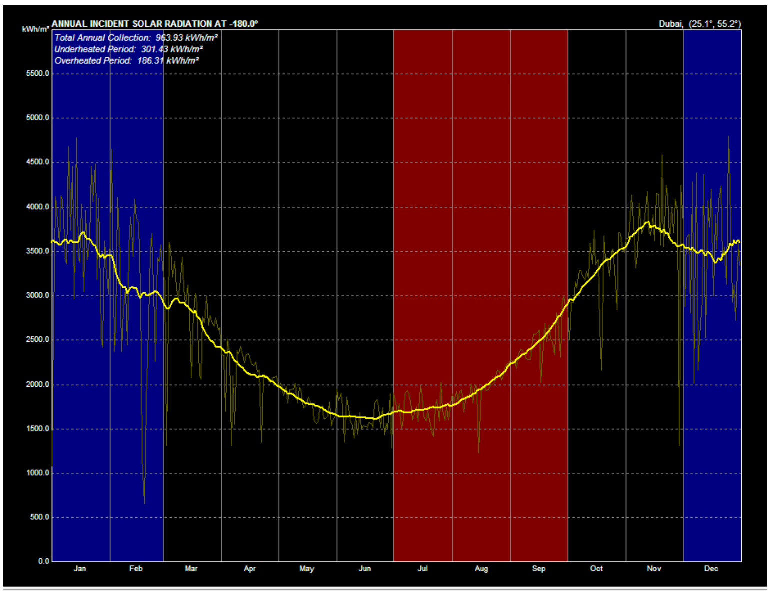


Figure 3.3, Solar radiation, Source (Ecotect)

Annual Solar Radiation

1. Thick yellow line represents the 30 day running average
2. Thinner, darker line shows the actual recorded total daily solar radiation
3. Red and blue areas of the graph indicate the three hottest and coldest months respectively

A psychometric Chart

A psychometric chart describes the relationship between dry-bulb temperature, and relative humidity, on the horizontal and the vertical axes respectively. The thermal comfort zone is defined according to temperature and relative humidity, as well as the occupant's involvements such as clothing and activity level. The UAE psychometric chart reflects the natural lack of outdoors comfort zones, where the climate is plotted outside the comfort zone in summer.

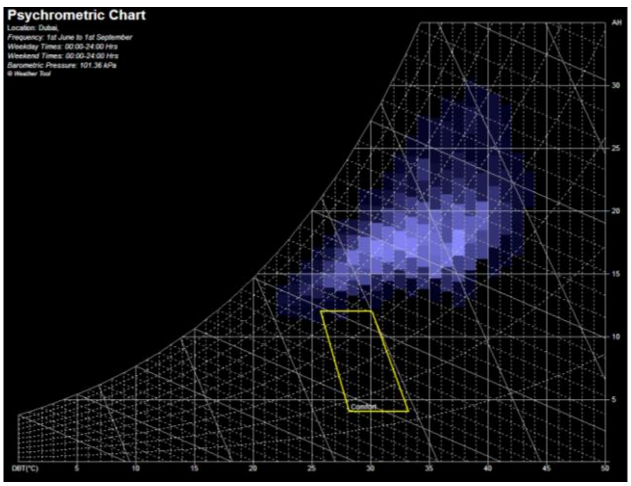


Figure 3.4, A psychometric chart of Dubai in Summer, Source (Ecotect)

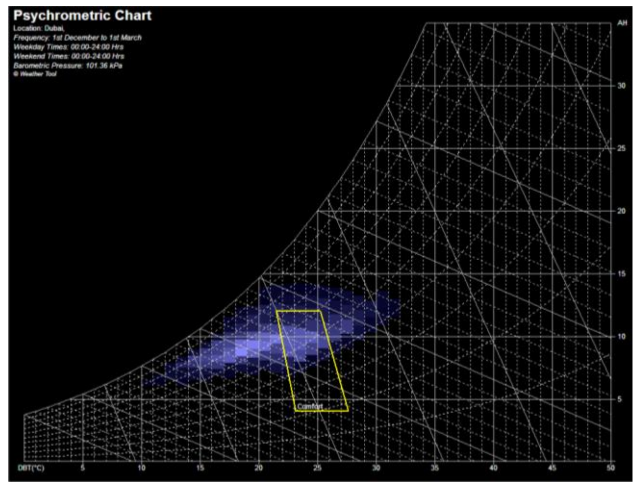


Figure 3.5, A psychometric chart of Dubai in Winter, Source (Ecotect)

Wind Analyzing

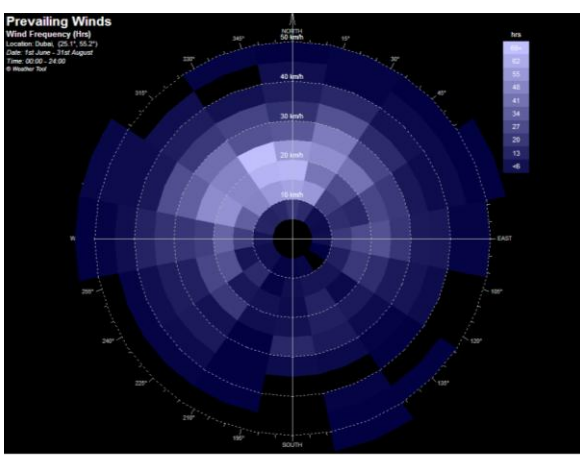


Figure 3.6, Wind Rose in Dubai in Summer, Source (Ecotect)

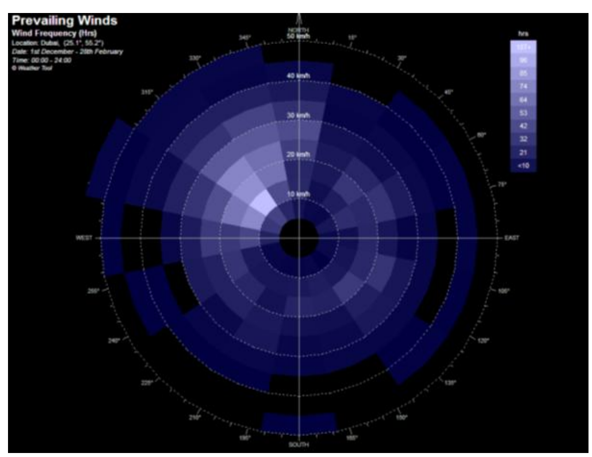


Figure 3.7, Wind Rose in Dubai in Winter, Source (Ecotect)

3.6 Conclusion of Climate Analyzing

The following graph shows the climate characteristic of Dubai.
From the graph it's shown that from the middle of February it's getting hot and need air conditioning. The temperature starts rising from this month and reaches to the highest point which is on middle of July and then start to decreasing.

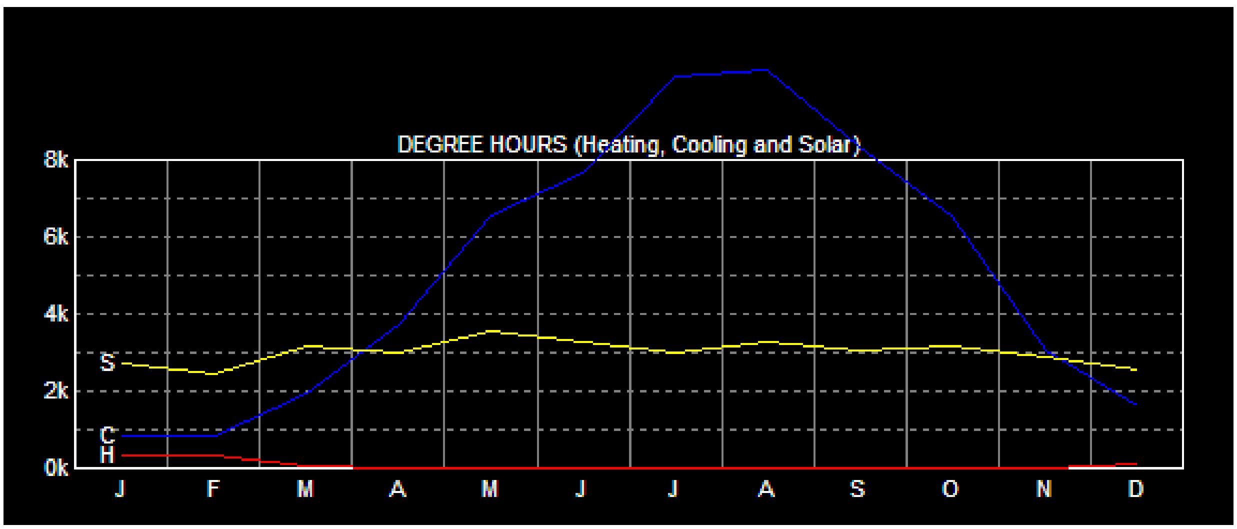


Figure 3.8, Climate Analyzing, Source (Ecotect)

During its long summers that can last more than five months, Dubai becomes extremely hot and humid. In the autumn and spring its climate is rather pleasant and in the winter the temperature seldom drops below 10 degrees Celsius. In this hot and humid climate, walking in palm groves can be an enjoyable experience even on hot summer days, and if there is breeze under the shade of the palms, one does not feel any discomfort form the weather.

Chapter 4. Result and Discussion

4.1 Models

Based on the previously described proposal, two existing building are generated in Ecotect software. The residential villa and the multi story's residential building (Fig 4.1, 4.2). As discussed in previous chapter, the highest range of building are devoted for residential used. The aim of study of two buildings is to find out the effect of green roof on thermal performance of the different types of residential building. First, by selecting the mid rise level with different heights which provide the shade through the surface will be measured and simulate and the second, selecting the villa with different design on roof which also provide the shade through the surface will be measured and simulate.

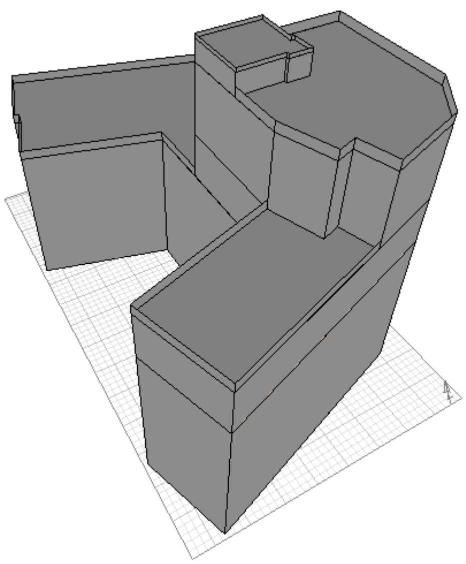


Figure 4.1, Residential Mid rise Building, G+M+9, Source (Ecotect)

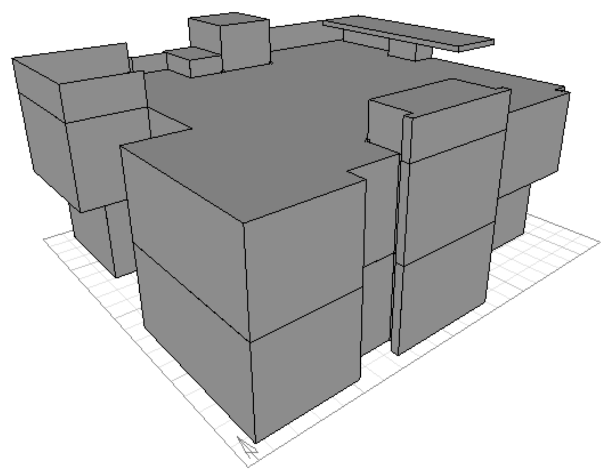


Figure 4.2, Residential Villa, G+1, Source (Ecotect)

4.2 step 1. Solar Radiation, Heat Transfer

The main focus for this study is to investigate the intensity of solar radiation striking on external surfaces of two building before it enters into the internal space.

And the second step is to investigate the total solar radiation, which is goes to internal spaces of the building. This can be particularly useful when considering the shading requirements on a building.

4.2.1 Conventional Roof

Roofs are more than just “functional components” for the protection of the building structure. Roofs give character to individual buildings and entire city districts. For this part of research, “Ecotect” is used to simulate data for cumulative incident solar radiation on horizontal surface on monthly and year.

Solar insulation is always given as an average value in Wh/m^2. So, two different building models with different orientation and area have been simulated during summer, winter and whole year.

The first method, which is has to draw the buildings in Ecotect and simulate the total solar radiation and heat transfer which will affect on building during the summer and winter time (Fig 4.3, 4.4, 4.5, 4.6). Whereas the second method is one run for whole year.

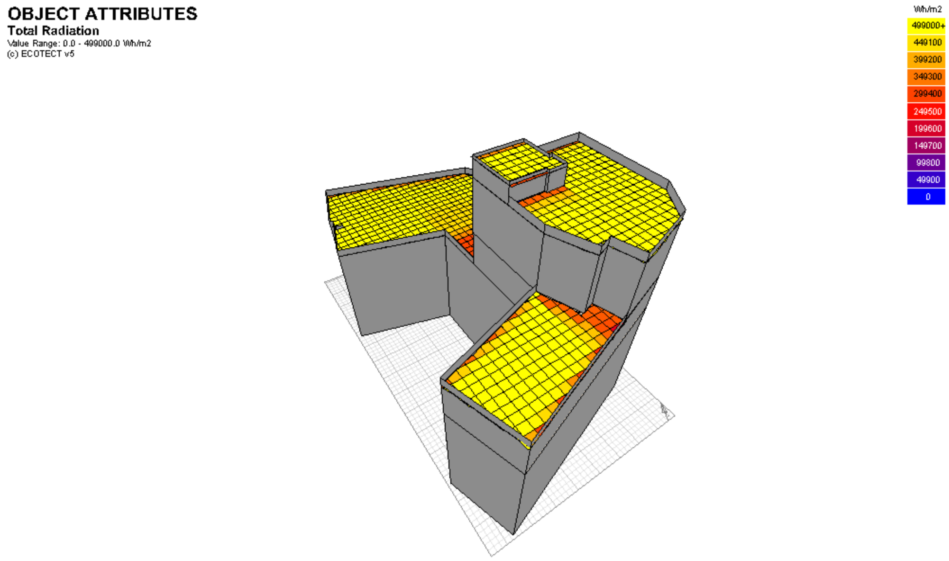


Figure 4.3, (Mid rise Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Summer

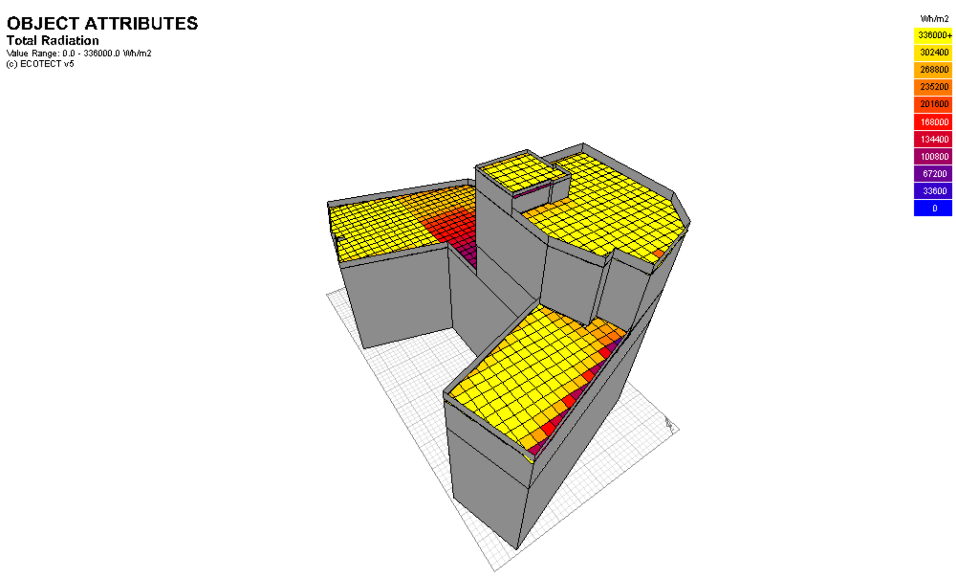


Figure 4.4, (Mid rise Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Winter

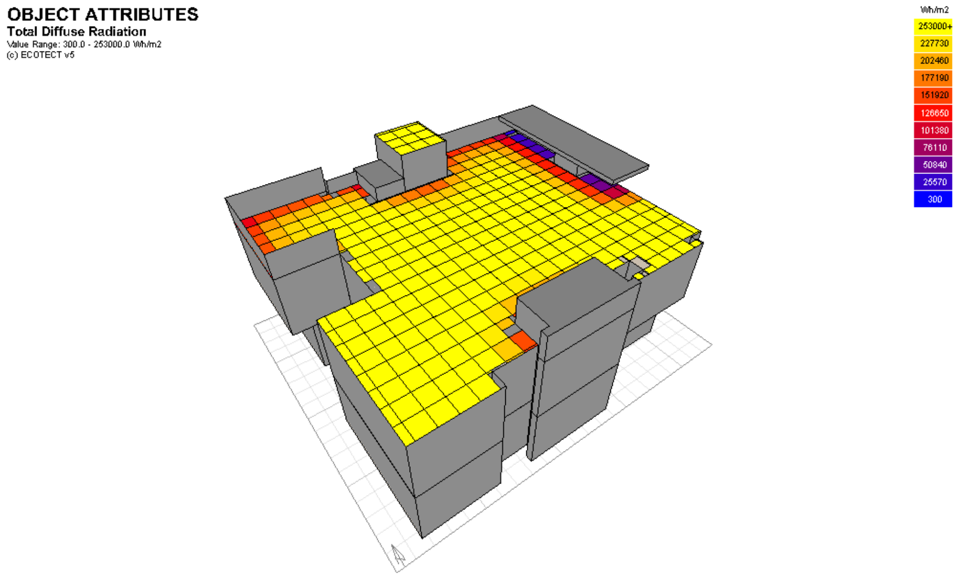


Figure 4.5, (Villa Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Summer

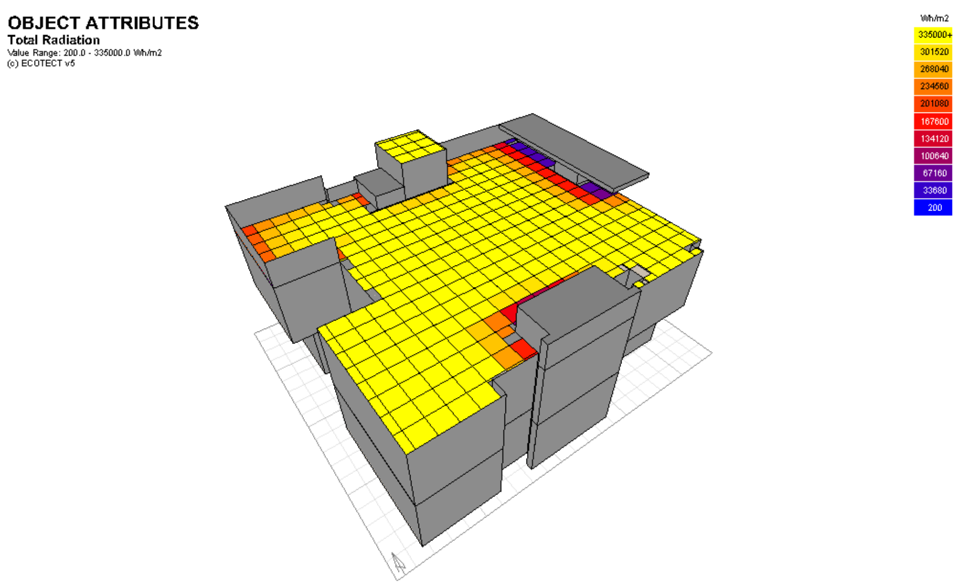


Figure 4.6, (Villa Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Winter

Solar gain: Sun radiation will passes through the atmosphere and some of it will be absorbed and reflected by air molecules, water vapor, clouds, dust, pollution, forest fires and volcanoes which is called this diffuse radiation however, the solar radiation which is reached to the surface without being diffused will called direct solar radiation.

Following tables shows the solar radiation into the building, which will affect on normal roof of each building during summer and wintertime.

Table 4.1, Ecotect calculates the annual solar radiation through the Summer

Building Type	Annual Solar Radiation of the Roof (Summer, Wh/m^2)
Midrise Residential Building (G+M+9)	424,231 Wh/m^2
Villa (G+1)	438,197 Wh/m^2

Table 4.2, Ecotect calculates the annual solar radiation through the Winter

Building Type	Annual Solar Radiation of the Roof (Winter, Wh/m^2)
Midrise Residential Building (G+M+9)	255,258 Wh/m^2
Villa (G+1)	287,961 Wh/m^2

Following Figures shows the calculations of the total solar radiation for the subdivided surface through the year:

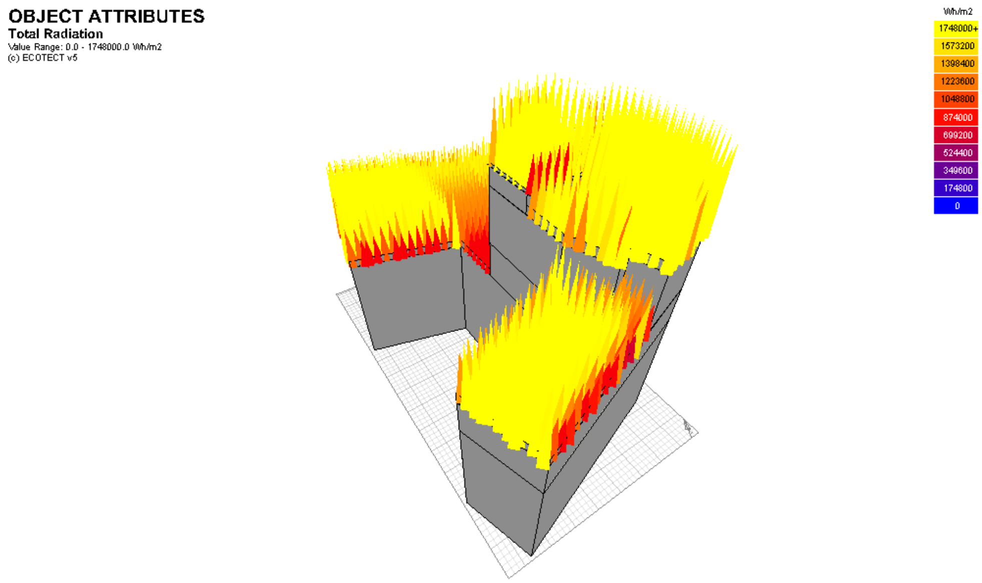


Figure 4.7, (Mid rise Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the year

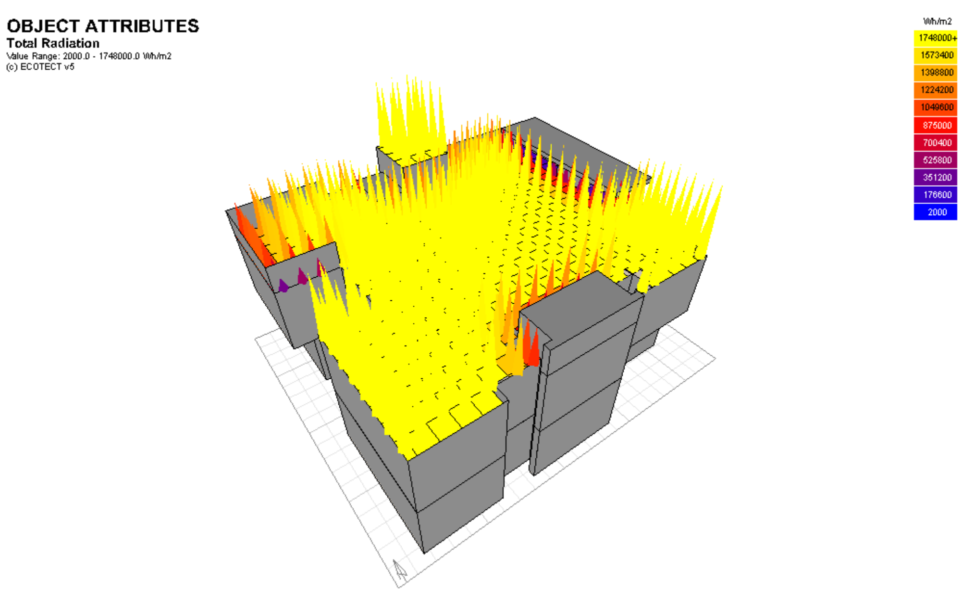


Figure 4.8, (Villa Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the year

Following table shows the total solar radiation, which is affected on two building during the year:

Table 4.3, Ecotect calculates the annual solar radiation through the Year

Building Type	Annual Solar Radiation of the Roof (Whole Year, Wh/m²)
Midrise Residential Building (G+M+9)	1,431,948 Wh/m²
Villa (G+1)	1,524,697 Wh/m²

Solar radiation will be absorbed on the internal surfaces of the building through conduction. For the aim of this study, is to find the total radiation, which will be in internal spaces. Following calculation shows the heat transfer through solar radiation into internal space of each building in summer and wintertime:

1. Midrise Residential Building (G+M+9) through the <u>summer</u>

Total Solar Radiation (Wh/m²)	*	Total Area of the Roof (m²)	=	Wh
424,231 Wh/m²	*	1,917.27 m²	=	813,365,369.37 Wh
813,365,369.37 Wh	/	Total Built up area (m²)	=	Internal solar gain
813,365,369.37 Wh	/	257,664.53 m²	=	3,156.68 Wh/m²

2. Villa Residential (G+1) through the <u>summer</u>

Total Solar Radiation (Wh/m²)	*	Total Area of the Roof (m²)	=	Wh
438,197 Wh/m²	*	358 m²	=	156,874,526 Wh
156,874,526 Wh	/	Total Built up area (m²)	=	Internal solar gain
156,874,526 Wh	/	711 m²	=	220,639.27 Wh/m²

3. Midrise Residential Building (G+M+9) through the <u>winter</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
255,258 Wh/m^2	*	1,917.27 m^2	=	489,398,505.66 Wh
489,398,505.66 Wh	/	Total Built up area (m^2)	=	Internal solar gain
489,398,505.66 Wh	/	257,664.53 m^2	=	1,899.36 Wh/m^2

4. Villa Residential (G+1) through the <u>winter</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
287,961 Wh/m^2	*	358 m^2	=	103,090,038 Wh
103,090,038 Wh	/	Total Built up area (m^2)	=	Internal solar gain
103,090,038 Wh	/	711 m^2	=	144,993.02 Wh/m^2

The measurements show that the amount of solar radiation which is falling on internal space of the building through the year. Therefore, the internal solar radiation will be different in summer and winter. Following calculation shows the solar internal space of each building through the year:

1. Midrise Residential Building (G+M+9) through the <u>year</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
1,431,948 Wh/m^2	*	1,917.27 m^2	=	2,745,430,941.96 Wh
2,745,430,941.96 Wh	/	Total Built up area (m^2)	=	Internal solar gain
2,745,430,941.96 Wh	/	257,664.53 m^2	=	10,655.05 Wh/m^2

2. Villa Residential (G+1) through the <u>year</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
1,524,697 Wh/m^2	*	358 m^2	=	545,841,526 Wh
545,841,526 Wh	/	Total Built up area (m^2)	=	Internal solar gain
50,726,669 Wh	/	711 m^2	=	767,709.60 Wh/m^2

The measurements and result of solar radiation which is falling on internal space of the building through the summer, winter and year have been summarized, Table 4.4. Therefore, the internal solar radiation will be different at any times of the year.

Table 4.4, Result of simulation of the annual internal solar gain of each building

Building Type	Annual Internal Solar Gain (Whole Year, Wh/m²)	Annual Internal Solar Gain (summer) Wh/m²	Annual Internal Solar Gain (winter) Wh/m²
Midrise Residential Building (G+M+9)	10,655.05 Wh/m²	3,156.68 Wh/m²	1,899.36 Wh/m²
Villa (G+1)	767,709.60 Wh/m²	220,639.27 Wh/m²	144,993.02 Wh/m²

4.2.2 Green Roof

Two different building models with different orientation and built up area have been simulated and analyzed during summer, winter and whole year. As discussed in literature review green roof provide the shade into roof surface and this will reduce the total amount of heat into the building. As so many research paper and studied mentioned that the covered vegetation/grass roof surface can provide shade in the roof surface, so, by applying the one plate surface on top of the roof surface can provide the same shade of the grass into the surface.

Therefore, in this part of research will calculate the roof with green shading devises in two residential buildings, thus unwanted solar gain is a major contributor towards unnecessary building energy consumption, particularly in hot and humid climate. Using the shading devices is an important role for controlling the sun radiation and also it's an important aspect of many energy efficient building design strategies. Therefore, green roofs have the potential to improve the thermal performance of a roofing system through shading, insulation, evapotranspiration and thermal mass, thus reducing a building's energy demand for space conditioning (Karen Liu, 2003).

According to literature reviews and so many research paper; the different plants and vegetation which is on the roofing will block the direct sun radiation and keep the area cool by shading, and also evaporative cooling from the plants, additional insulation values from different vegetation and plants. Additionally, the higher gain of solar radiation is in summer, which the energy performance affects, so in this case green roof shading devices will be necessary.

The first method, according to the simulation program in different companies in Dubai such as Atkin's and WSP environmental group, it has to draw and simulate the buildings in Ecotect with shading devices with some voids which solar radiation can go through it and these shading devices act as green roof on the area and the size is around 40% to 50% of the roof and simulate the total solar radiation which will affect on building during the summer and winter time (Fig 4.9, 4.10). Whereas the second method is one run for whole year.

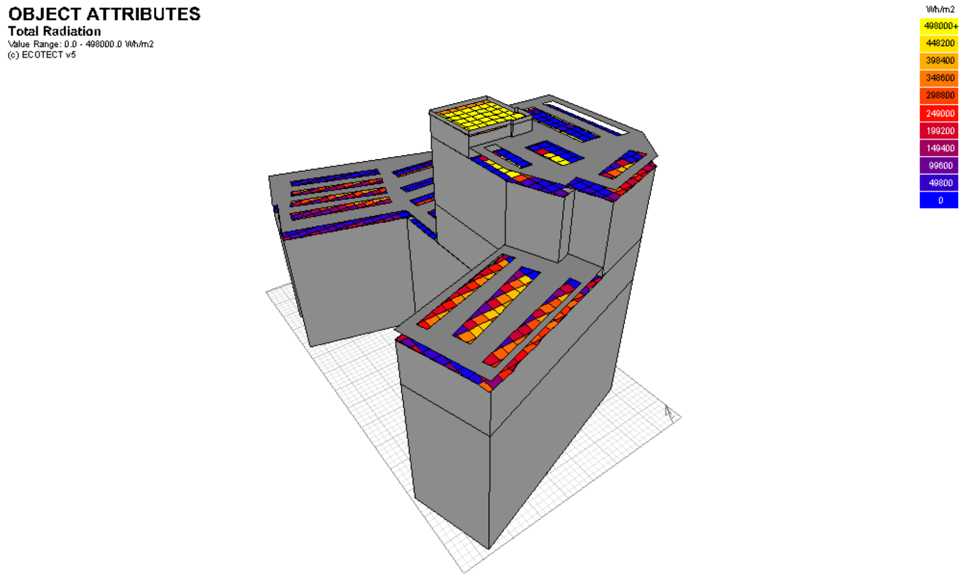


Figure 4.9, (Mid rise Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Summer

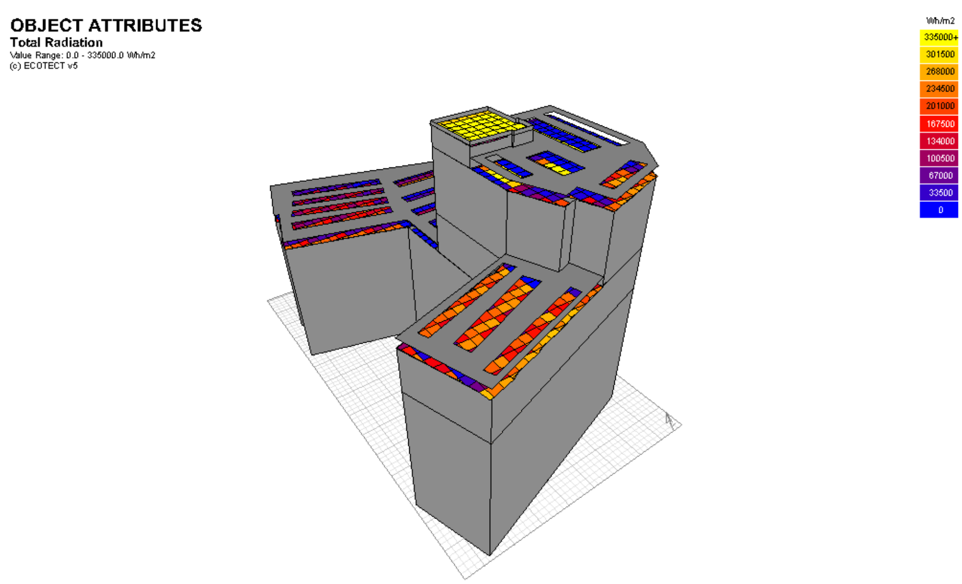


Figure 4.10, (Mid rise Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Winter

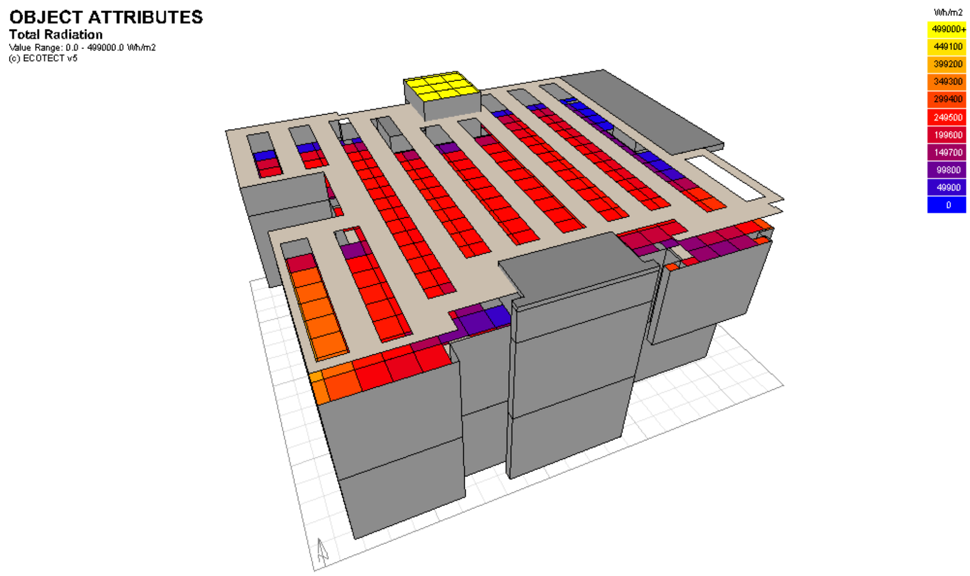


Figure 4.11, (Villa Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Summer

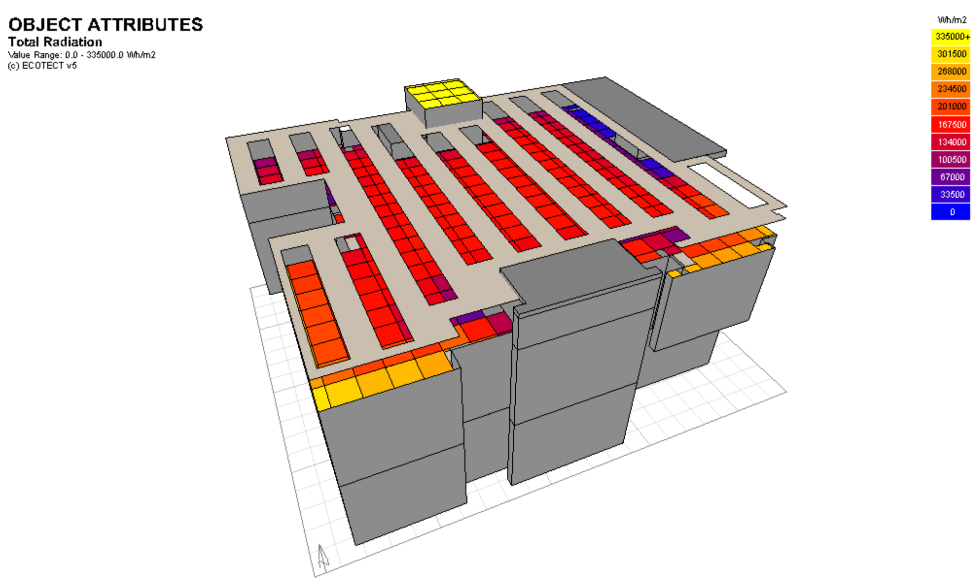


Figure 4.12, (Villa Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the Winter

Following tables shows the solar radiation into the building, which will affect on green roof of each building during summer and wintertime.

Table 4.5, Ecotect calculates the annual solar radiation through the Summer

Building Type	Annual Solar Radiation of the Roof (Summer, Wh/m²)
Midrise Residential Building (G+M+9)	173,302 Wh/m²
Villa (G+1)	212,291 Wh/m²

Table 4.6, Ecotect calculates the annual solar radiation through the Winter

Building Type	Annual Solar Radiation of the Roof (Winter, Wh/m²)
Midrise Residential Building (G+M+9)	116,866 Wh/m²
Villa (G+1)	153,134 Wh/m²

Following Figures shows the calculations of the total solar radiation for the subdivided surface (green roof on the top) through the year:

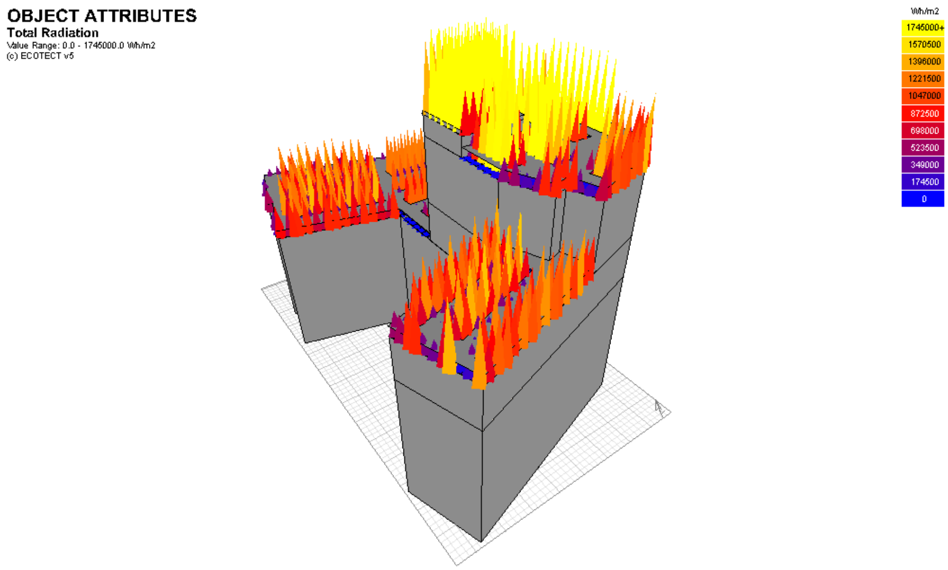


Figure 4.13, (Mid rise Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the year

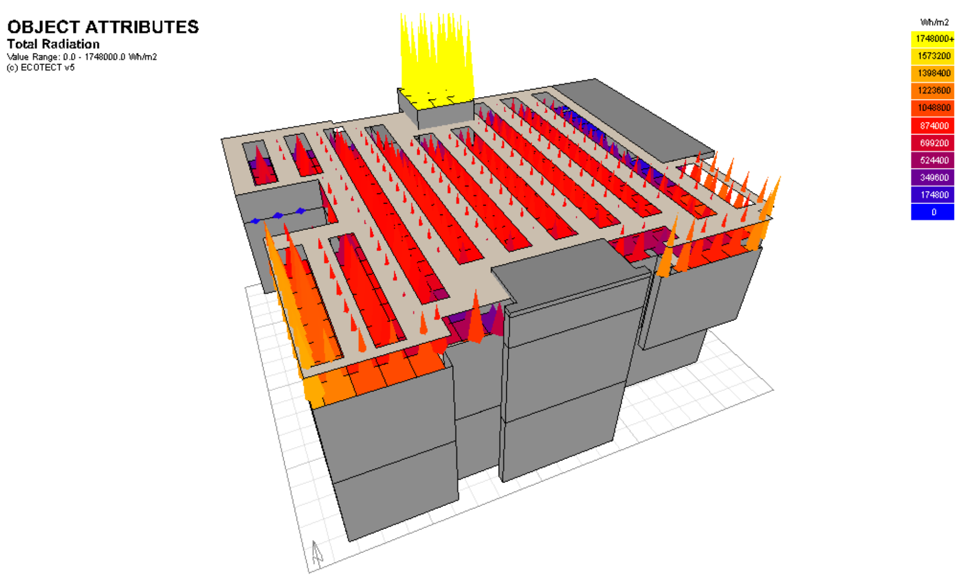


Figure 4.14, (Villa Residential) Ecotect calculates the annual solar radiation for the subdivided surface through the year

Following table shows the total solar radiation for the roof, which has greenery on the year:

Table 4.7, Ecotect calculates the annual solar radiation through the Year

Building Type	Annual Solar Radiation of the Roof (Whole Year, Wh/m²)
Midrise Residential Building (G+M+9)	605,360 Wh/m²
Villa (G+1)	770,240 Wh/m²

The heat will transfer from the roof into internal spaces. However, by applying the green roof can control and reduce the heat, which is goes through the internal spaces of the building. Following calculation shows the heat transfer through green roof into internal space of each building in summer and wintertime:

1. Midrise Residential Building (G+M+9) through the <u>summer</u>

Total Solar Radiation (Wh/m²)	*	Total Area of the Roof (m²)	=	Wh
173,302 Wh/m²	*	1,917.27 m²	=	332,266,725.54 Wh
332,266,725.54 Wh	/	Total Built up area (m²)	=	Internal solar gain
332,266,725.54 Wh	/	257,664.53 m²	=	1,289.53 Wh/m²

2. Villa Residential (G+1) through the <u>summer</u>

Total Solar Radiation (Wh/m²)	*	Total Area of the Roof (m²)	=	Wh
212,291 Wh/m²	*	358 m²	=	76,000,178 Wh
76,000,178 Wh	/	Total Built up area (m²)	=	Internal solar gain
76,000,178 Wh	/	711 m²	=	106,891.95 Wh/m²

3. Midrise Residential Building (G+M+9) through the <u>winter</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
116,866 Wh/m^2	*	1,917.27 m^2	=	224,063,675.82 Wh
224,063,675.82 Wh	/	Total Built up area (m^2)	=	Internal solar gain
224,063,675.82 Wh	/	257,664.53 m^2	=	869.59 Wh/m^2

4. Villa Residential (G+1) through the <u>winter</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
153,134 Wh/m^2	*	358 m^2	=	54,821,972 Wh
54,821,972 Wh	/	Total Built up area (m^2)	=	Internal solar gain
54,821,972 Wh	/	711 m^2	=	77,105.44 Wh/m^2

The measurements show that the amount of solar radiation which is falling on internal space of the building through the year. Therefore, the internal solar radiation will be different in summer and winter. Following calculation shows the solar internal space of each building through the year:

1. Midrise Residential Building (G+M+9) through the <u>year</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
605,360 Wh/m^2	*	1,917.27 m^2	=	1,160,638,567.2 Wh
1,160,638,567.2 Wh	/	Total Built up area (m^2)	=	Internal solar gain
1,160,638,567.2 Wh	/	257,664.53 m^2	=	4,504.45 Wh/m^2

2. Villa Residential (G+1) through the <u>year</u>

Total Solar Radiation (Wh/m^2)	*	Total Area of the Roof (m^2)	=	Wh
770,240 Wh/m^2	*	358 m^2	=	275,745,920 Wh
275,745,920 Wh	/	Total Built up area (m^2)	=	Internal solar gain
275,745,920 Wh	/	711 m^2	=	387,828.29 Wh/m^2

The measurements and result of solar radiation which is falling on internal space of the building through the summer, winter and year have been summarized, Table 4.8. Therefore, the internal solar radiation will be different at any times of the year.

Table 4.8, Result of simulation of the annual internal solar gain of each building

Building Type	Annual Internal Solar Gain (Whole Year, Wh/m²)	Annual Internal Solar Gain (Summer, Wh/m²)	Annual Internal Solar Gain (Winter, Wh/m²)
Midrise Residential Building (G+M+9)	4,504.45 Wh/m²	1,289.53 Wh/m²	869.59 Wh/m²
Villa (G+1)	387,828.29 Wh/m²	106,891.95 Wh/m²	77,105.44 Wh/m²

Simulations shows that roofs surface in Dubai are always expose to the sun through the day. For a midrise buildings, solar radiation toward the horizontal surface are exposed more that low rise buildings, however, the building which has been chosen for simulation in this research have different level and heights that can block some of the solar radiation so, it's shown the roof surface of villa received more solar radiation through year. Following figures shows the final result of internal solar gain of both buildings (Conventional roof and green roof), (kWh/m²):

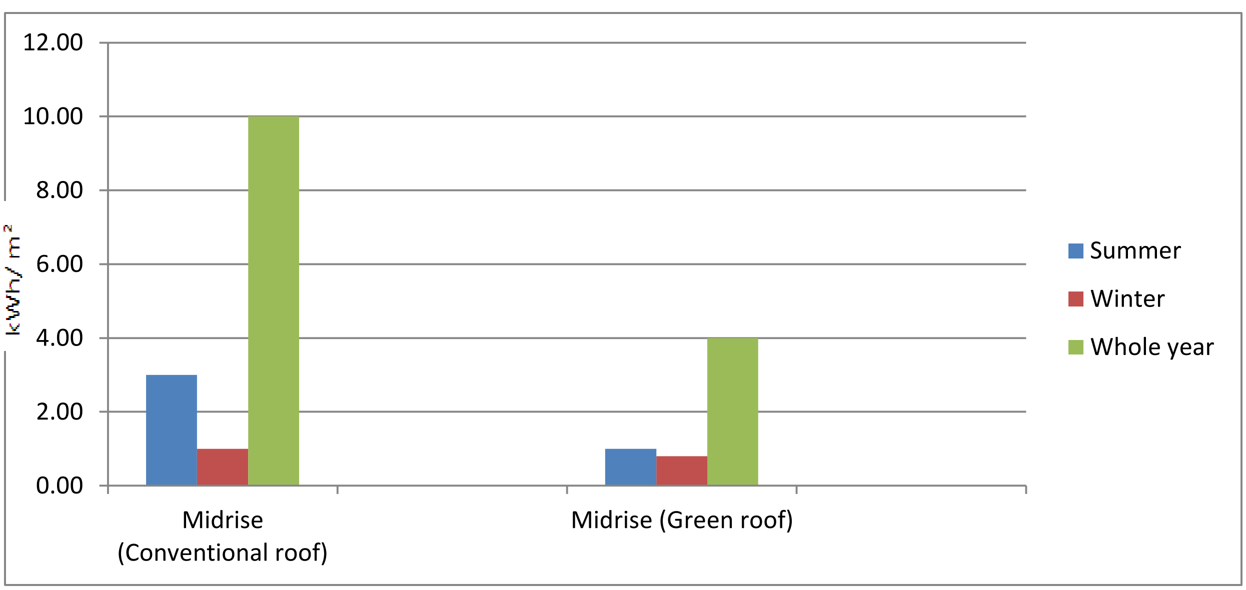


Figure 4.15, Final result of internal solar gain of midrise building (kWh/ m²)

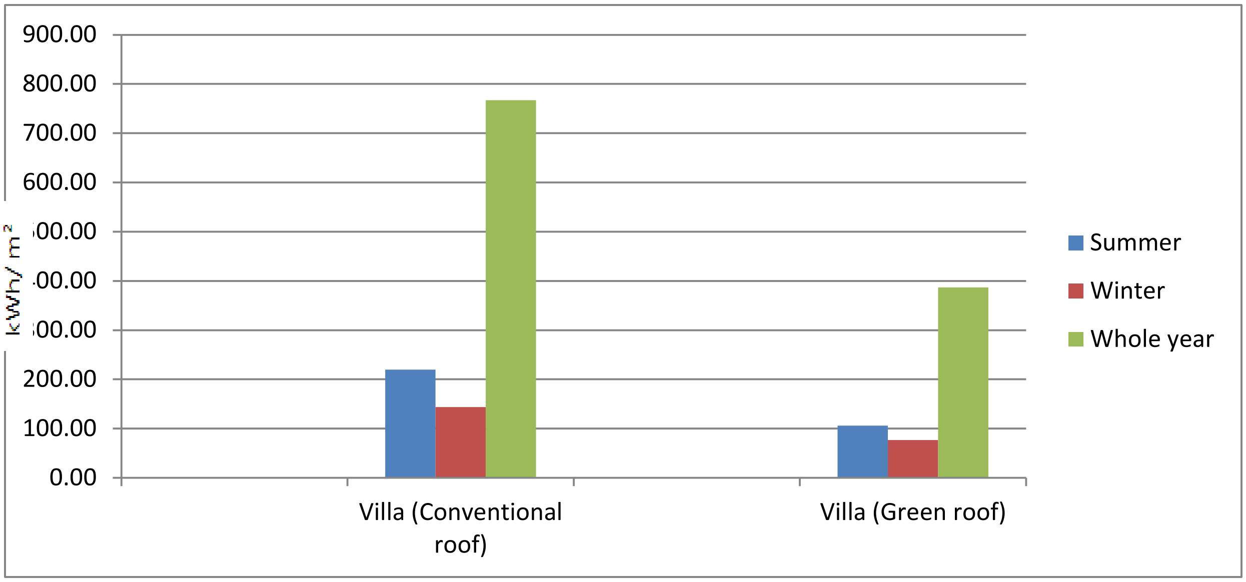


Figure 4.16, Final result of internal solar gain of Villa (kWh/ m²)

To controlling the solar radiation is an important part of building design in a hot and humid climate, it represents one of the most significant sources of potential summer heat gains. So, by having the greenery on the roof surface can provide shade on the roof surface of a building and can control the total internal solar gain. Therefore, simulation shows that green roof systems are recognized as providing greater thermal performance and roof insulation for the buildings. Cultivating healthy plants requires careful consideration of light and shade on surface. By applying the 40% – 50% roof with greenery can reduce the total internal solar gain of the buildings. However, the solar radiation in low rise building is more than mid rise, this because of built area of the building. By having so many levels in the building solar radiation will receive less into all levels. So the low rise receives more internal solar radiation.

In both case green roof can reduce energy. Following figure shows the percentage of reducing the internal solar gain of each building), (kWh/m²):

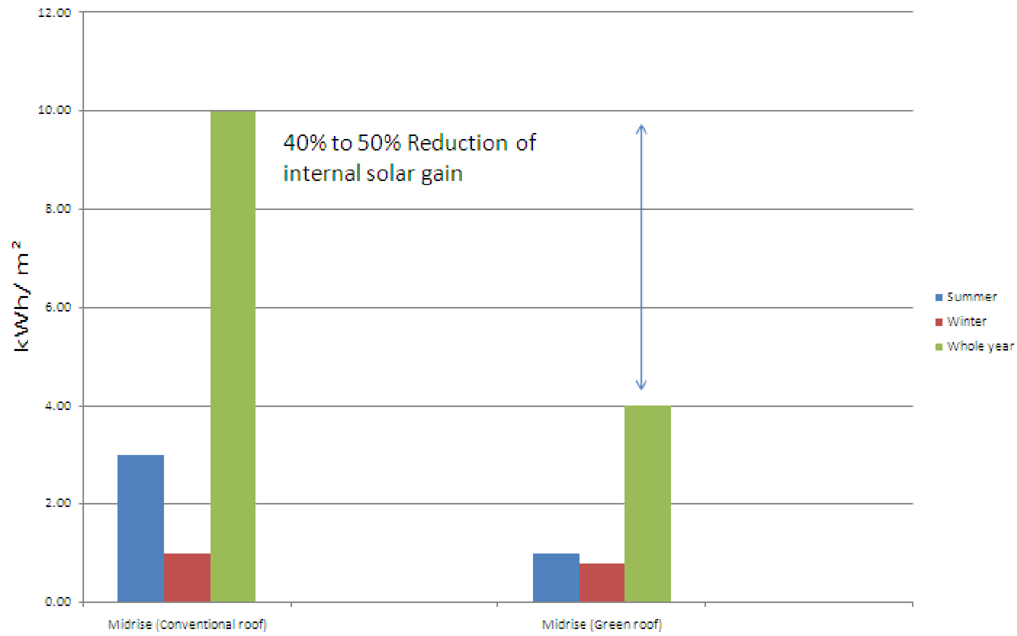


Figure 4.17, Final result of internal solar gain of midrise building (kWh/ m²)

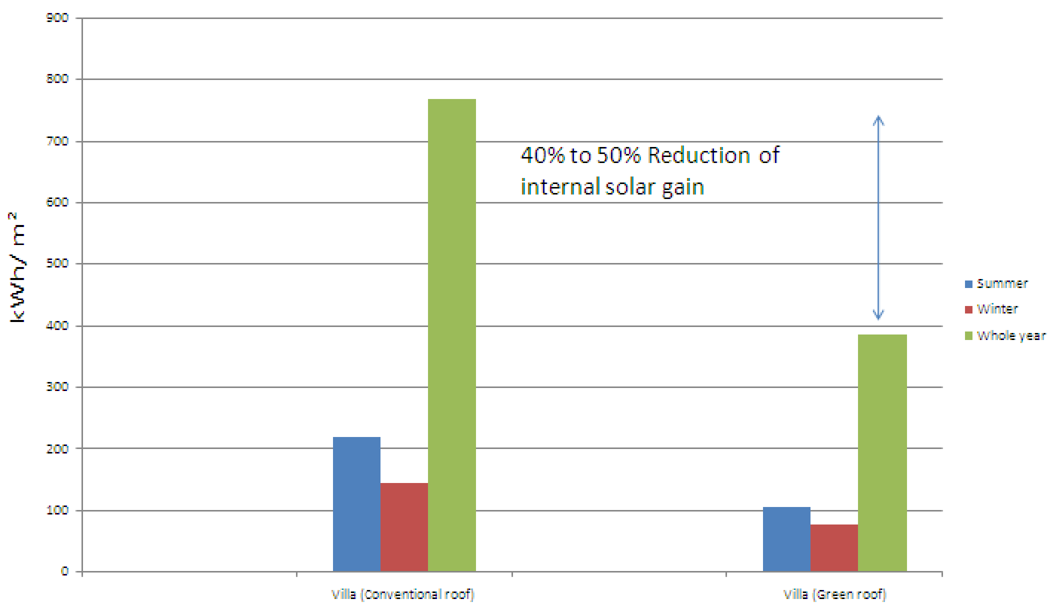


Figure 4.18, Final result of internal solar gain of villa (kWh/ m²)

4.3 Step 2. Different U-Value

For this step of the research, different materials with different U-value have been simulating. As it's discussed in previous chapter for finding the U-value of the roof or green roof, first, should find the R-value, which is the measure of thermal resistance of insulation materials. It is a more familiar unit for measuring and designing the insulating performance of a building component. The greater R-value, the greater the insulating value. Therefore, by knowing the resistance of a material can predict how fast the heat will flow through it and also can compare materials with each other. Following formula shows the measuring of the R-value:

(R) Value = D/K ($m^2 \cdot K/W$)

Table 4.9, R-Value

Value	Description	Unit
R	Thermal resistance	[($m^2 \cdot K$)/W]
K	Conductivity	[W/(m K)]
D	Thickness of the material	m

Moreover, the reciprocal of the U-value is the air-to-air resistance in W/m^2 K, and then U-value is measured in W/m^2 K. Therefore, Low U-value good insulation and high U-value bad insulation.

(U) Value = 1 / Rt

Table 4.10, U-Value

Value	Description	Unit
U	Heat Coefficient Flow	[W/ (m^2 K)]
Rt	Total Thermal resistance	[W/ (m^2 K)]

4.3.1 U-Value of Conventional Roof

Diffreent study and research has been shown the benefits of insulation and U-value. Therefore U-value can be improved and better contribute to deliver in different climates. U-values are also a first guide for a designer and architect in setting the thermal performance of the building envelope. Following figure shows the detail of the roof (Fig 4.19).

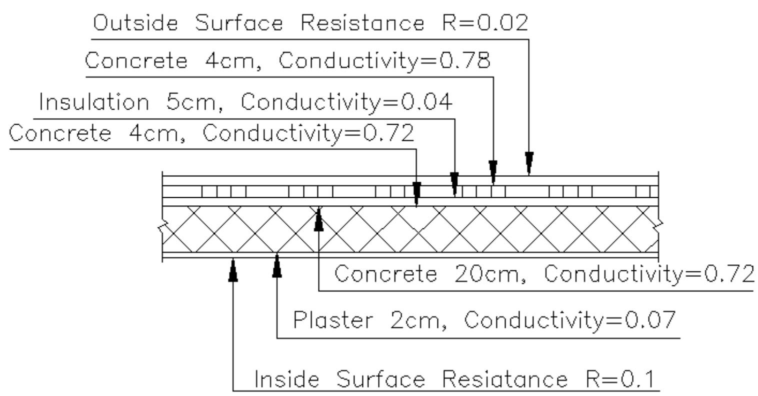


Figure 4.19, Roof Detail (Caad Drawing)

By having all the data can easily calculate the U-value of the roof.

(U) Value = 1 / Rt (W/ m^2K)
(U) Value = 1 / Rao + D1/K + D2/K + … + Rai

Following formula and table shows the way to calculate the R-value of each material, by having the R-value can easily calculate the U-value of the conventional roof.

(R) Value = D/K (m^2·K/W)

Table 4.11, Detail of the roof (Material, Thickness, Conductivity)

Roof Materials	Thickness (m)	Conductivity (W/m K)
Inside air resistance		0.1 W/m K
Plaster	0.02 m	0.07 W/m K
Concrete	0.2 m	0.72 W/m K
Concrete	0.04 m	0.72 W/m K
Insulation	0.05 m	0.04 W/m K
Concrete	0.04 m	0.78 W/m K
Outside air resistance		0.02 W/m K

D/K = 0.02/0.07 + 0.2/0.72 + 0.04/0.72 + 0.05/0.04 + 0.04/0.78 =

D/K = 0.28 + 0.27 + 0.05 + 1.25 + 0.05 = 1.9 ($m^2 \cdot K/W$)

(U) Value = 1 / 0.1 + D1/K + D2/K + … + 0.02

(U) Value = 1 / 0.1 + 1.9 + 0.02 = 1 / 2.02

(U) Value = 0.4 ($W/ m^2 K$)

4.3.2 U-Value of Green Roof

A green roof system is an extension of the existing roof which involves a high quality water proofing and root repellant system, a drainage system, filter cloth, a lightweight growing medium and plants and each component of the system may be installed separately. Following figure shows the detail of the roof (Fig 4.20).

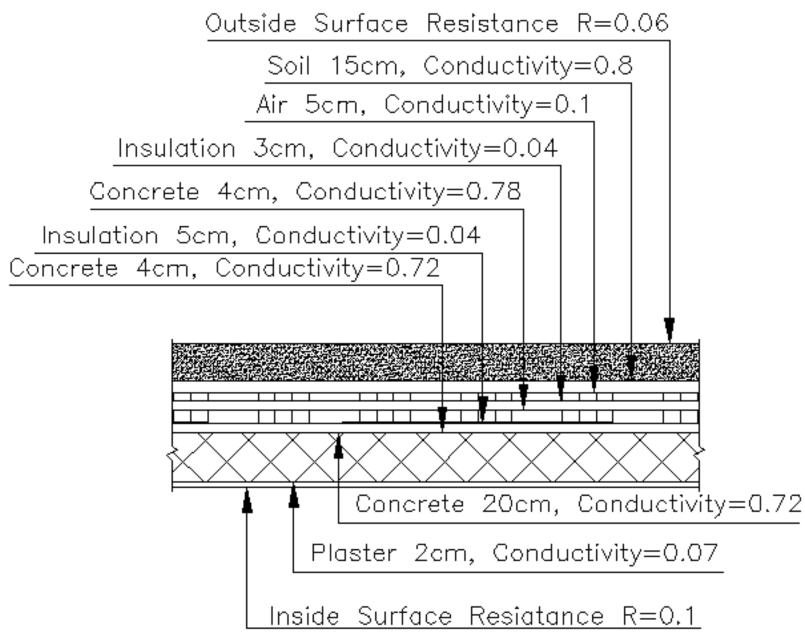


Figure 4.20, Detail of Green Roof (Caad Drawing)

Same method will be used in this part to calculate the U-value of the green roof.

(U) Value = 1 / Rt (W/ m^2 K)
(U) Value = 1 / Rao + D1/K + D2/K + … + Rai

Following formula and table shows the way to calculate the R-value of each material:

(R) Value = D/K (m^2·K/W)

Table 4.12, Detail of the roof (Material, Thickness, Conductivity)

Roof Materials	Thickness (m)	Conductivity (W/m K)
Inside air resistance		0.1 W/m K
Plaster	0.02 m	0.07 W/m K
Concrete	0.2 m	0.72 W/m K
Concrete	0.04 m	0.72 W/m K
Insulation	0.05 m	0.04 W/m K
Concrete	0.04 m	0.72 W/m K
Insulation	0.03 m	0.04 W/m K
Air	0.05 m	0.1 W/m K
Soil	0.15 m	0.8 W/m K
Outside air resistance		0.06 W/m K

D/K = 0.02/0.07 + 0.2/0.72 + 0.04/0.72 + 0.05/0.04 + 0.04/0.78 + 0.03/0.04 + 0.05/0.1 + 0.15/0.8 = ($m^2 \cdot K/W$)

D/K = 0.28 + 0.27 + 0.05 + 1.25 + 0.05 + 0.75 + 0.5 + 0.18 = 3.33 ($m^2 \cdot K/W$)

(U) Value = 1 / 0.1 + D1/K + D2/K + … + 0.06

(U) Value = 1 / 0.1 + 3.33 + 0.06 = 1 / 3.49 = 0.28

(U) Value = 0.28 (W/m2 K)

Heat has been calculated and measures of insulation U-values from roof surface and green roof surface. Therefore, the green roof because of different layers on the surface of the roof and vegetation will reduce heat while the conventional roof is oposide and absorb more heat. The roof which, has low U-value has a good insulation than high U-value. Following table summarized the U-values of each roof.

Table 4.13, Result of U-value (Both roofs)

(U) Value Conventional Roof	0.4 [W/ (m² K)]
(U) Value Green Roof	0.28 [W/ (m² K)]

After finding the U-value of each roof now, should divided the result of U-value and the multiply by the result of internal solar gain of green roof (Section 4.2.2) of each buildings and compare the result.

Different between the results of U-value: 0.28 /0.4 = 0.7

Table 4.14, Result of simulation of the internal solar gain of each building green roof with U-value

Building Type	Internal Solar Gain with U-value (Whole Year, Wh/m²)	Internal Solar Gain with U-value (summer, Wh/m²)	Internal Solar Gain with U-value (winter, Wh/m²)
Midrise Residential Building (G+M+9)	4,504.45 * 0.7 = 3,153.11	1,289.53 * 0.7 = 902.67	869.59 * 0.7 = 608.71
Villa (G+1)	387,828.29 * 0.7 = 271,479.80	106,891.95 * 0.7 = 74,824.36	77,105.44 * 0.7 = 53,973.80

Following figure shows the reduction of internal solar gain of each building (Green roof, Green roof * U-value), (kWh/ m²).

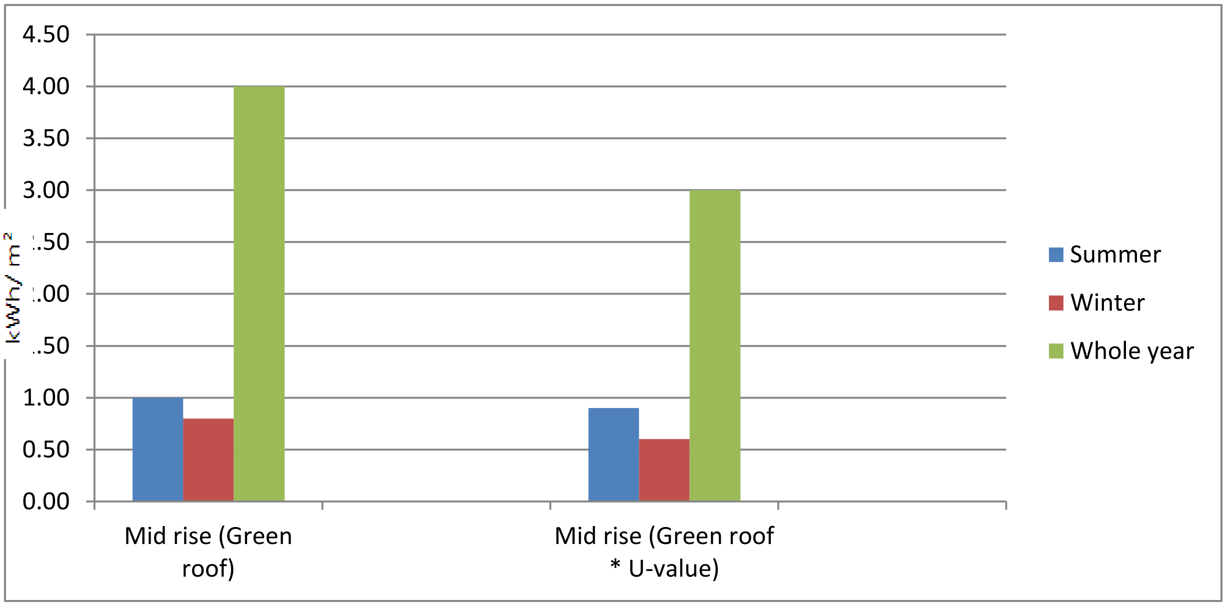


Figure 4.21, Final result of internal solar gain of green roof with internal solar gain of green roof with U-value of Midrise (kWh/ m²)

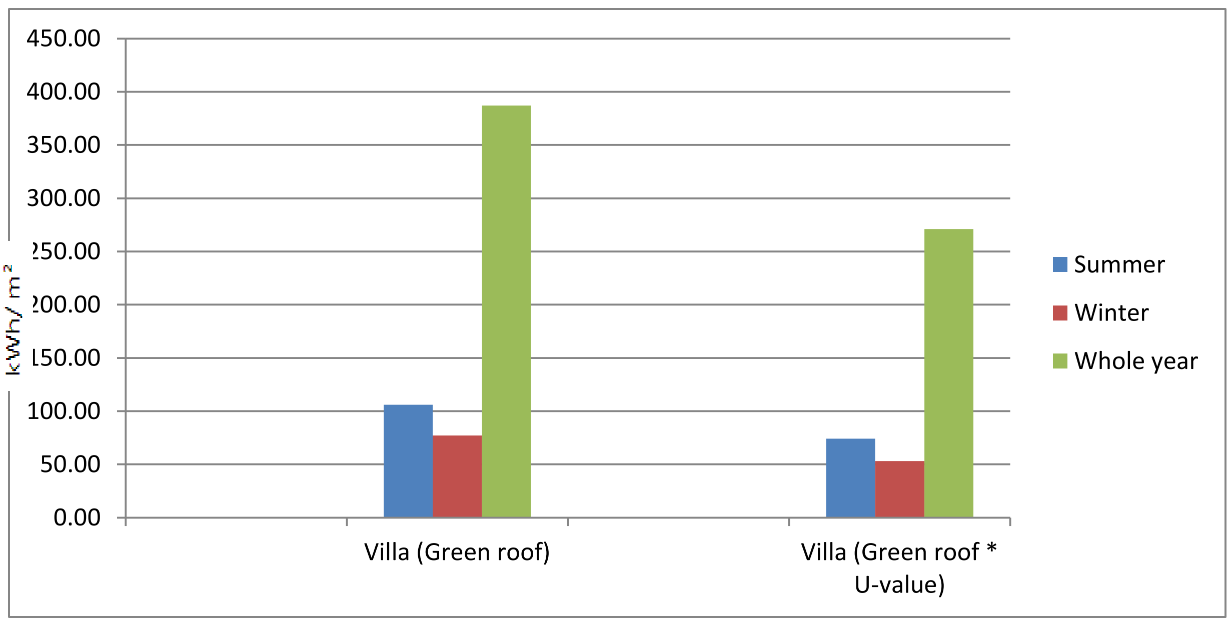


Figure 4.22, Final result of internal solar gain of green roof with internal solar gain of green roof with U-value of Villa (kWh/ m²)

As it's discussed previously low U-value is better insulation. As it's shown in the graphs total internal solar radiation of each building will be reduced with the U-value of the green roof.

4.4 Step 3. Evapotranspiration

Before discussing evapotranspiration, and effects on the energy and temperature, it is necessary to study and understand the thermal properties of water that allow it to be so efficient at transferring heat. The specific heat capacity of each substance is the amount of energy which is needed to raise the temperature of 1 g of each substance by 1°C. Therefore, specific heat capacity is a physical characteristic property. So, different material or substance has different specific heats. It's measured in joules per gram per degree Kelvin (J g−1 K−1). Water has a very high specific heat: it takes 4.19 J to raise the temperature of 1 g or 1 ml of water by 1°C. Following tables shows specific heat capacity of common material which is used in the building.

Table 4.15, Heat capacity of common material in the building

Material	Specific heat capacity (J g−1 K−1)
Aluminium	0.921 J g−1 K−1
Iron	0.46 J g−1 K−1
Concrete	0.88 J g−1 K−1
sandstone	1.09 J g−1 K−1

For every gram of water on a plant's surface that is heated by one degree Celsius (Kelvin) the plant is losing 4.19 joules of energy. Evapotranspiration is the combined loss of water from a plant to the atmosphere that occurs through evaporation from a plant's surface, and transpiration, which comprises plant water uptake for use in its biological functions. Evapotranspiration is an important tool, its helps to cool plants and constantly occurs at various temperatures. Therefore, in higher temperatures may lead to an increase in the amount of water being evaporated and transpired. However, the processes of evapotranspiration plants are able to maintain a low surface temperature to compare to the other substances, even during especially hot and humid periods. Despite most plants absorb a great deal of solar radiation, which means its relatively low albedo. The amount of heat that is removed from a plant's surface due to water's high specific heat allows plants and the soil beneath them to maintain temperatures cooler than many other surrounding materials.

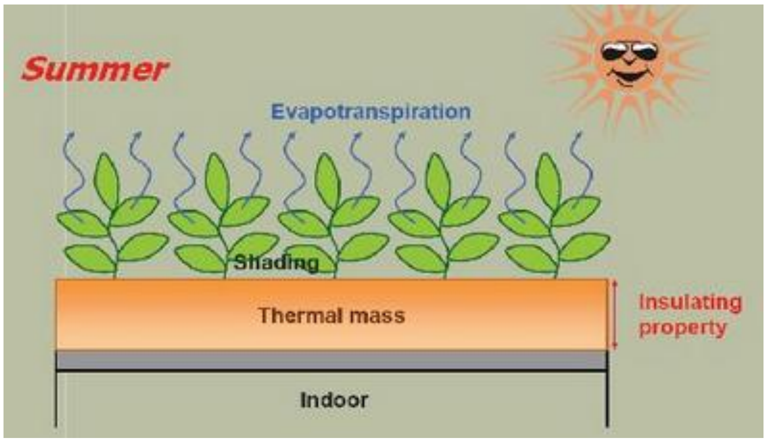


Figure 4.23, Evapotranspiration, Source (http://www.columbia.edu/~grh2113/pages/greenroofs.html)

As it's simulate and calculate of green roof main website, that every m² of green roof consumes around 10 Liters/day of water. So, by having this information it's easily to find out the specific heat capacity of one liter of water to evaporate (Watts/liter). And then multiply that with the liters/day and then by numbers of days in year. The watt, which is finding is needed to be divided by the area of green roof, which is 50% of total roof for each building and finally to divided to the total built area of each building. Following formula shows the amount of heat which is absorbed or lost by a substance during a physical change.

$Q = m\ c\ \Delta T$

Density of water is 1 gm/cc, 1 liter = 1000 cc

1Watt hour = Joul / 3600
4.19 Joul/ 3600 = 0.001163889 Watt Hour

Table 4.16, Heat which is absorbed or lost by a substance during a physical change

Value	Description	Unit
Q	Quantity of heat in joules	J
m	Mass of the substance acting as the environment	g
c	Specific heat capacity (4.19 for H_2O)	[J/(g °C)]
ΔT	Change in temperature = Tfinal – Tinitial	°C

Q = 1000 * 0.001163889 * 60°C * 10 litter

Q = 700 watt/litter

700 * 365 (days in year) = 255,500 Wh/yr (during the year)

Table 4.17, Result of specific heat capacity of one liter of water to evaporate during the year and multiply by green roof are then divided by total built area

Type of the building	Evaporation through the year * Green area on the roof / Total built area
Mid rise Residential Building (G+M+9)	255,500 * 958.63 / 257,664.53 = 950 (W/m^2)
Villa (G+1)	255,500 * 179 / 711 = 64,324 (W/m^2)

The number that it's shown in the table should substract with the internal solar gain of green roof and fined the benefits from the evaporation. Following table and graphs shows the detail:

Table 4.18, Result of simulation of the internal solar gain of each building with evaporation

Building Type	Internal Solar Gain with Evaporation (Whole Year, Wh/m²)	Internal Solar Gain with Evaporation (Summer, Wh/m²)	Internal Solar Gain with Evaporation (Winter, Wh/m²)
Midrise Residential Building (G+M+9)	4,504.45 - 950 = 3,554.45	1,289.53 - 950 = 339.53	869.59 - 950 = 80.41
Villa (G+1)	387,828.29 - 64,324 = 323,504.29	106,891.95 - 64,324 = 42,567.95	77,105.44 - 64,324 = 12,781.44

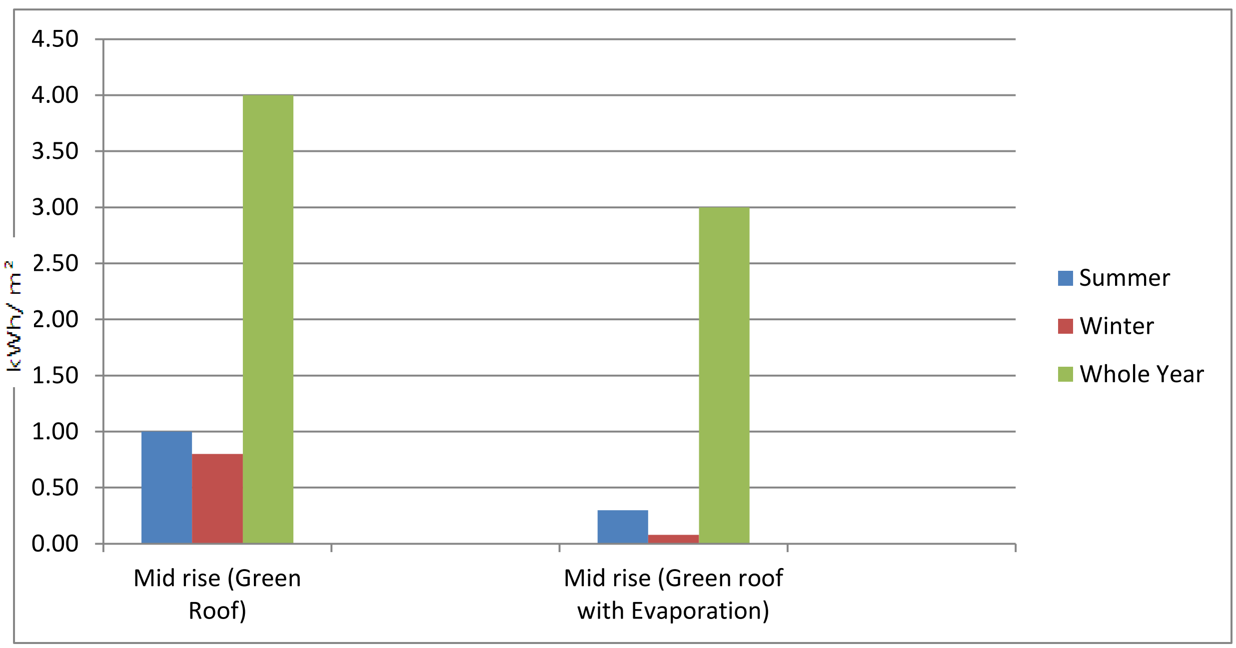


Figure 4.24, Final result and comparing the internal solar gain of green roof with internal solar gain with evaporation of Mid rise (kWh/ m²)

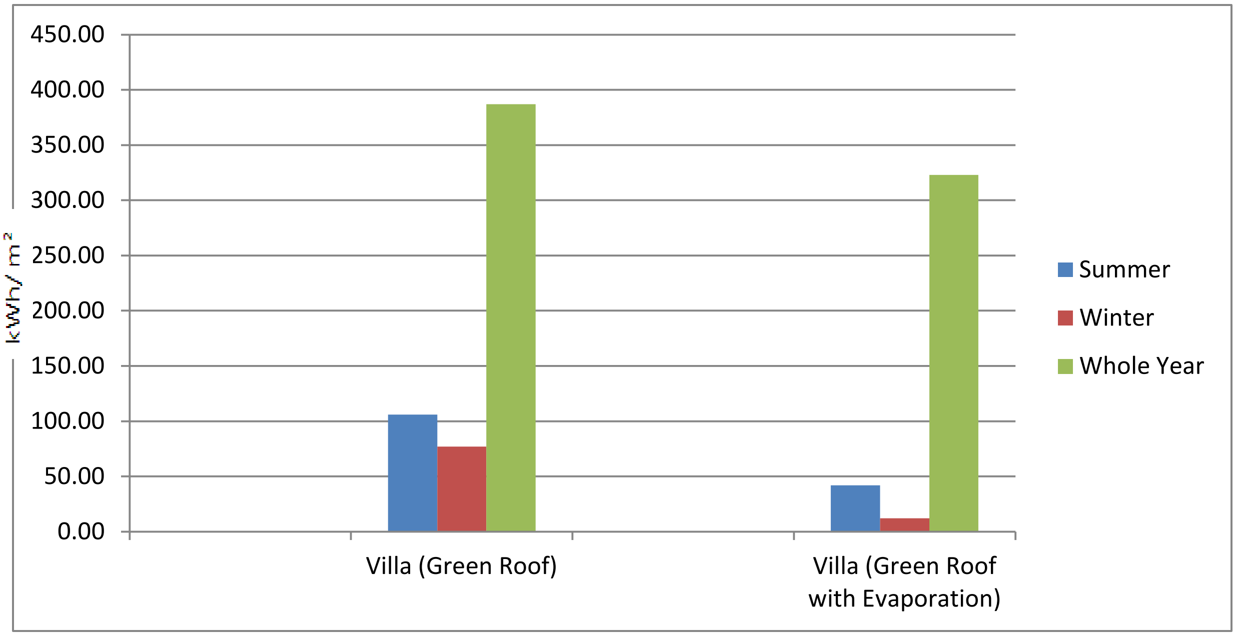


Figure 4.25, Final result and comparing the internal solar gain of green roof with internal solar gain with evaporation of Villa (kWh/ m²)

The graphs shows that with evaporation the internal solar gain of the building will be reduced so, the building can have benefits from that.

By examining the specific heat, and evapotranspiration and affect on green roofs, its shows the better understanding of how and why green roofs are able to maintain significantly lower temperatures than conventional roofs which is made of more traditional building materials. By virtue of water's high specific heat, evapotranspiration, green roofs should be able to consistently maintain cooler temperatures, and a cooler roof surface, than their more traditional counterparts. Also, by evaporating water on green roof can reduces the Urban Heat Island Effect especially in the summer.

4.5 Step 4. Types of Plants

By creating the different kind of plants on the roof can bring the natural on the building and have some recreational space for gathering and relaxing for the residence. Different kind of plants can reduce the urban heat island. Therefore, Green roofs can provide new opportunities for urban agriculture. One example of this is the Fairmount Waterfront Hotel in Vancouver who uses their green roof to grow herbs, flowers, and vegetables on its accessible roof, saving its kitchen in food costs. So many papers and researched has been investigated the effect of different types of plants and density on green roof. Plants have an effect on the climates. The types of plants which is used for green roof depends on so many factors such as:

- Climate
- Sun exposure
- Water requirement
- Soil condition

By analyzing those entire factor can choose the best plants in different climate. Some plants can do very well in thin layer of soil, and others require more depth for growing. For deeper soil need more weight which is means to have stronger structure to support the roof. Following table shows the different type of plants in different growing medium.

Table 4.19, Different types of plants in different thicknesses

Different growing medium	Description	Image
Plants suitable for 5 cm	Shallow rooting varieties that can survive in poor, dry and humid conditions. Sedum (stone crop) and delosperma (ice plant) they are succulents and can retain water during dry spells also can usually survive 2 to 3 weeks without irrigation. And has a variety of colours, both leaves and flowers, and mature at different times of the year.	 Figure 4.26, Different types of plants, Source (Personal Achieve)

Plants suitable for 10 cm	Deeper soil can make possible for wider range of plantings. Several species of grasses, alliums, herbs and wildflowers can be used in this type.	 Figure 4.27, Different types of plants, Source (Personal Achieve)
Plants suitable for 15 cm	Much larger variety can be used. Such as Grasses, columbines, asters, and Black eyed Susan are all viable at with this deep a roof.	 Figure 4.28, Different types of plants, Source (Personal Achieve)

Plants can control the temperature and the humidity into the building and the same time can protect the building from the solar radiation, and winds. Generally, the solar radiation of the external temperature and the relative humidity can be reducing as its pass through covered planted roof.

In hot and humid region like Dubai, it's better to used local plants which is available and easy to access and also at the same time consumes very less water and can stay longer without irrigation. Local plants can also have another benefit such as transportation and cost. Following tables shows some plants which is used for green roof in Dubai:

Table 4.20, Sesuvium Portulacastrum (Sea Pursaline)

Type of plant	Sesuvium Portulacastrum (Sea Pursaline)
Description	Sea Purslane is a native, can found on the sea coasts areaand it grows on the ocean and sea side. The thick, fleshy leaves are borne on succulent, reddish green stems that branch regularly forming dense stands close to the ground. Small, showy pink flowers are borne more or less continually throughout the year. Each flower will be opens for only a few hours on each day. These plants help build the dunes by catching sand in between stems and leaves.
Image	 Figure 4.29, Sesuvium Portulacastrum (Sea Pursaline), Source (http://www.flowersofindia.net/catalog/slides/Sea%20Purslane.html)

Table 4.21, Agave

<table>
<tr><td>Type of plant</td><td>Agave</td></tr>
<tr><td>Description</td><td>Agave nectar syrup is produced in hot and humid region. Different types of Agave:

• Blue Agave (Agave tequilana)
• Salmiana Agave (Agave salmiana)
• Green Agave, Grey Agave
• Thorny Agave
• Rainbow Agave

Agave nectar is sweeter than honey, though less viscous. Agave has some more benefits such as:

• Water potential was higher in sandy soils than in rocky soils and root growth was greatest in sandy soils.
• Agave deserti had twice the biomass and root surface area in sandy soils over rocky soils.
• Deserti leaf's water potential was the same at rocky and sandy sites but the Agave transpiration rate was twice as high in rocky soils.</td></tr>
<tr><td>Image</td><td>
Figure 4.30, Agave
, Source (http://www.google.com/images?hl=en&q=Agave&bav=on.2,or.r_gc.r_pw.&um=1&ie=UTF-8&source=og&sa=N&tab=wi&biw=1280&bih=699)</td></tr>
</table>

Table 4.22, Aloe Vera

Type of plant	Aloe Vera
Description	Aloe Vera grows in arid and hot climates and is widely distributed in Africa, India, UAE and other hot and arid areas. Also it's used as herbal medicine. Therefore, this plant is very useful in the treatment of wound and burn healing, minor skin infections, Sebaceous cyst, diabetes, and elevated blood lipids in humans. By having this type of plant on the roof can easily access and used for different purpose and the same time provide the beauty and reduce the sun radiation.
Image	 Figure 4.31, Aloe Vera , Source (http://www.google.com/images?hl=en&q=Aloe+Vera&bav=on.2,or.r_gc.r_pw.&um=1&ie=UTF-8&source=og&sa=N&tab=wi&biw=1280&bih=699)

Finally, as discussed previously factors for selecting different plant material are:

- Design intent
- Aesthetic
- Environmental conditions
- Media composition and depth
- Installation methods
- Maintenance

Regardless of the desired aesthetic effect, climate has a major impact on plant selection for green roof. Dubai climate is hot and humid and mostly there in no rain. Therefore, it is necessary to find the plants which can stay longer without watering.

Chapter 5. Conclusions and Recommendations

5.1 Conclusions

In this study, an environmental assessment of the effect of green roof in thermal performance of the building has been conducted in the content of hot and humid climate (Dubai). The study included the introduction of history of green roof and … and literature review of different research papers on green roof and thermal performance of the building that had been done in different area and different climate with different methodology and simulations. These studies elaborated in the other climate and countries and lacked methodological testing and validation in given climate (hot and humid). A computer simulation has been developed by Ecotect and used for this study. Consequently, all finding were based on the simulation result and other formula to calculate the other matters.

The study has outlined four steps: firstly, two different residential houses modeling have been chosen for simulating process, and analyzing the heat transfer (sun radiation) from the roof into the building. Secondly, simulating and comparing the U-value of the conventional roof with the U-value of the green roof. Thirdly, by finding the heat capacity of water and measuring the heat evaporation of green roof. Finally, choosing and selecting the best plants for green roof in Dubai.

In the first step, two types of residential building have been selected and have been evaluating the two type of the roof (conventional roof and green roof) on each building and the result compared qualitative and quantitatively between the types of roof, which are solar radiation and heat transfer into the building. The study concluded that the energy reduction through the green roof is less than the conventional roof. Therefore, green roof methods were recommended in both buildings to control the sun radiation and heat transfer into the interior spaces of the building. The Ecotect software analyzes showed that by having the greenery (surface with opening) could provide the shade and control the direct sun radiation into the building.

In the second step, the simulation shows that the U-value of green roof is lower than the conventional roof. Having the good thermal protection can reduce the thermal load especially in the summer. As it's shown in the research the U-value of each conventional roof on each building has been calculating. Thus, before measuring the U-value first, should find the R-value, which is the measure of thermal resistance of insulation materials. The greater R-value, the greater the insulating value. But in the other hand the low U-value the greater insulation value. After measuring the U-value of the conventional roofs, then should measuring the U-value of green roofs in both buildings. The result shows that the roof with greenery has lower U-value, which is better insulation. Then by finding the average of U-value and multiply with the internal solar gain of green roof can see the reduction of internal solar gain of the building. So, this means that temperature will be decreased with green roof and low U-value into the building. Moreover, green roof can act very well in 4 to 6 story's building because of the total roof area and built area. For high rise building the total built area is a lot and this will help to have less internal solar gain but in another hand for low rise and mid rise building is opposite and it's better to have green roof and control the solar radiation and heat transfer into the buildings.

In the third step, simulation from the mathematical formula should find the heat capacity of water and then find how much will be during the year. The result should be multiply with green roof area and then divided by the total built area. By examining the specific heat, and evapotranspiration and affect on green roofs, its shows that better understanding of how and why green roofs are able to maintain significantly lower temperatures than conventional roofs which is made of more traditional building materials. Also this will help to reduce the cooling load of the building.

In the forth step, as its discussed previously different thickness of soil and different plant will be recommended for different climate. Regardless of the desired aesthetic effect, climate has a major impact on plant selection for green roof. Dubai climate is hot and humid and mostly there in no rain. Therefore, it is necessary to find the plants, which can stay longer without watering. There are some expamles of plants for hot and humid climate of Dubai, Sesuvium Portulacastrum (Sea Pursaline), Aloe Vera, Agave … Nevertheless, different plants has different U-value, which also can reduce the thermal performance of the building.

Finally,It is important for designers and owners of real estate to be aware of the environment, health and the impact of building design and function. In recent years, there has been study a lot about the environmentally friendly and sustainable design. Improving the quality of life is a goal, which should be considering, and is certainly achievable when is starting to develop the land responsibly. Following graphs shows the final four steps of simulation and then the final table shows some benefits and drawback of conventional roof and green roof:

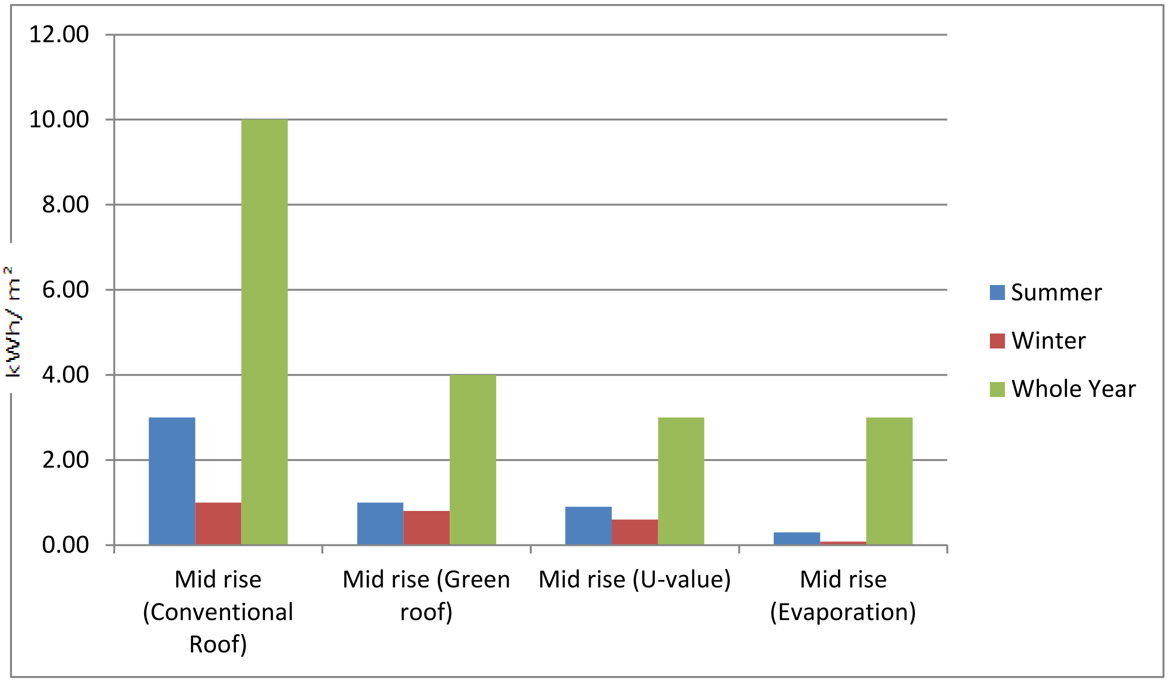


Figure 5.1 Summary of four steps (Conventional roof- Green roof- Evaporation and U-value) of Mid rise Building (kWh/ m²)

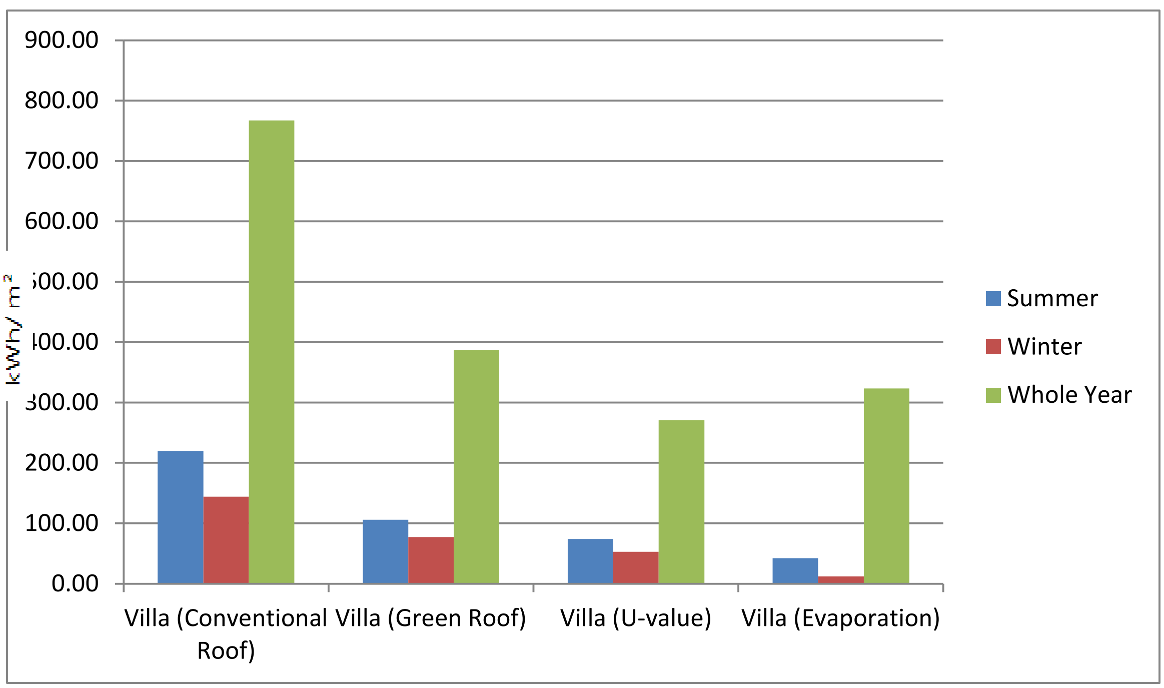


Figure 5.2 Summary of four steps (Conventional roof- Green roof- Evaporation and U-value) of Villa (kWh/ m²)

Table 5.1, Summary of benefits and drawback of conventional roof and green roof

Conventional Roof		Green Roof	
Benefits	Draw Back	Benefits	Draw back
Low dead Load	Maximize cooling load	Minimize cooling load	High dead Load
Low maintenance	Maximize internal solar gain	Minimize internal solar gain	High maintenance
Low cost	Maximize urban heat island	Evaporation cooling	High cost
	Maximize noise and pollution	Minimize urban heat island	
	Minimize the Insulation	Minimize noise and pollution	
		Maximize the Insulation	
		Food production	
		Recreational Space	
		Aesthetic	

5.2 Recommendations

The green roof model shows a significant role in the climate control and energy use reduction in hot and humid regions. Green roofs can help to reduce the problems such as energy, water, and environment which facing the society in the future years. Therefore, green roof technology can provide the air quality and reduce the pollution health and welfare in the urban. Hopefully this will lead to holistic green building better ventilation, shade, and microclimate, less energy reliance for the Dubai.

From the thermal maps of Dubai which shows that Dubai moves with high heat discharge on certain area on city. The material that is used for construction and darker material that is used on roads will shows that urban heat island. According to Dubai municipality study the rising temperature due to the city fast development over the year. So by having the landscape, greenery and green roof on top of the building can reduce thermal performance of the building and the same time reduce the heat island. So in this research it is recommended that further studies should continue in investigate both direct effect of green roof on the building and indirect effects of green roofs on urban heat island effect in Dubai.

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Appendices

Appendix A: Study of Extensive Green Roof and Intensive Green Roof

Study of Extensive Green Roof

Extensive green roofs generally provide greater biodiversity interest than intensive roofs, but are considered to be less appropriate in providing amenity and recreation benefits. Extensive roofs planted by succulents, mosses, wild flowers and grasses that are able to survive on the shallow low nutrient substrates that form their growing medium (Living roofs and walls). Although extensive green roofs having a thinner layer of substrate which is around 20–200mm and generally they have relatively lightweight. Because of little additional support, which is needed in the building the greater range of application is possible (Ayako Nagase, 2010, UK, Pages 318-327). Following table shows the twelve species and their ecological characteristics:

Table A.1, The twelve species and their ecological characteristics, Source (Brickell, 2003; Hubbard, 1984; Snodgrass and Snodgrass, 2006; Stephenson, 1994)

Plant name	Typical habitats
Armeria maritima	Coasts, immature soils over a wide range of rock types.
Origanum vulgare	Infertile, usually calcareous soils.
Prunella vulgaris	Grassland, typically associated with moist, moderately fertile soils.
	Short turf, particularly in lawns and permanent pasture.
Silene uniflora	Coastal cliffs, shingle and gravelly soils.
Sedum acre 'Minor'	Dry sand dunes and steeply sloping, S-facing exposure of rock
Sedum album 'Coral carpet'	It grows at very contrasting altitudes and in a great variety of soils.
Sedum rupestre	A multiple of settings from costal sand dunes to about 2000 m in the mountains.
Sedum spurium 'Coccineum'	On rocks in the middle and upper alpine zones.
Anthoxanthum odoratum	A wide range of grasslands and to a lesser extent, open habitats particularly on slightly acidic soils.
Festuca ovina	Dry habitats include xerophylly and an early shoot phenology and seed-set.
Koeleria macrantha	Infertile calcareous grassland and rock outcrops.
Trisetum flavescens	Dry grassland and, to a lesser extent, rocky habitats, particularly on base-rich soils.

Vegetation such as sedum doesn't need much watering; they can be survived more than 3 weeks without watering. However, it is very important to be aware of the different sedum species. Result with the different paper research shows that the S. spurium, Coccineum has a lower survivability without watering them.

By using the forbs or grasses, it should be to consider irrigation to maintain good visual quality. Moreover, all these depend on the environment, in microclimate, the thickness of substrate layer and type of substrate material will be considered. In temperate climate such as UK, they used plants for extensive roof which is fully covered from the drought, such as A. maritima, P. vulgaris, S. uniflora, K. macrantha, and T (Ayako Nagase, 2010, UK, Pages 318-327).

Study of Intensive Green Roof

It's better to design intensive green roofs for recreational area. Also it's referred to as roof gardens or terraces. In most cities, the extensive green roofs has more common than intensive green roof by a wide margin due to the latter's high load bearing requirement, high installation cost and maintenance (Getter, 2006). An intensive green roof, native woodland, was established in Hong Kon. The following table shows the environmental sensors and installation positions in the green roof monitoring experiment:

Table A.2, The environmental sensors and installation positions in the green roof monitoring experiment, Source (C.Y. Jim, 2011, Hog kon)

Site	Sensor	Measured enrvironmental parameter
A: Core	Soil moisture sensor	Rockwool moisture, soil moisture at 10 cm, 50 cm and 90 cm depth
	Air temperature sensor	Air temperature at 15 cm and 160 cm above the ground
	Soil temperature sensor	Soil temperature at 10 cm, 50 cm and 90 cm depth; tile temperature and concrete slab temperature
	Infrared temperature sensor	Surface temperature of soil with ground cover vegetation; surface temperature of tree canopy
	Relative humidity sensor	Relative humidity at 15 cm and 160 cm above the ground
	Dew point sensor	Dew point temperature at 15 cm and 160 cm above the ground
B: Periphery	Air temperature sensor	Air temperature at 15 cm and 160 cm above the ground; concrete slab temperature
	Infrared temperature sensor	Surface temperature of soil with ground cover vegetation; surface temperature of tree canopy
	Relative humidity sensor	Relative humidity at 15 cm and 160 cm above the ground
	Dew point sensor	Dew point temperature at 15 cm and 160 cm above the ground
C: Control	Temperature sensor	Air temperature above bare concrete roof
	Infrared temperature sensor	Surface temperature of bare concrete roof
	Relative humidity sensor	Relative humidity above bare concrete roof
	Dew point sensor	Dew point temperature above bare concrete roof
	Infrared temperature sensor	Surface temperature of bare concrete roof
	Pyranometer	Intensity and duration of solar radiation
	Anemometer	Wind speed and wind direction

Four depth of soil temperature have been measure, from 0 cm (on the soil surface), 10cm, 50cm, and 90cm below the surface. All these finding indicates that the thermal insulation effect by the substrate can be achieved by about 10cm of soil. Thus a thin layer of green roof soil is sufficient to prevent heat penetrating into the building. The tree canopy reduces solar radiation reaching the soil surface, but the trapped air increases air temperature near the soil surface. The substrate operates an effective heat sink to dampen temperature fluctuations. In winter, the subtropical green roof triggers notable heat loss from the substrate into the ambient air, and draws heat upwards from warmer indoor air to increase energy consumption to warm indoor air (C.Y. Ji, 2011, Hong Kon).

Based on the depth of the planting medium, usage of water, maintenance and the type of plants used, Green roofs are generally categorized as Intensive, Semi Intensive and Extensive Green Roofs Table A.3.

Table A.3, Diffreent types of Green Roof

Features	Type of green roofing	Type of green roofing	Type of green roofing
	Extensive	Semi Intensive	Intensive
Plantation	Sedum-herbs and ground covers with less water consumption	Grass, shrubs and ground covers. Edible plantation is also possible	Lawn, perennilas, shrubs, palms and trees
Irrigation Requirement	Very less (drip irrigation facility)	Medium (drip/sprinkler irrigation facility)	High (drip and sprinkler irrigation facility)
Maintenance	Low	Medium	High
Cost	Low	Medium	High
Utility	Thermal insulation for the building	Aesthetic enhancement and thermal insulation	Aesthetic enhancement, increades utility area and thermal insulation

Following figure shows the detail of extensive and intensive green roof:

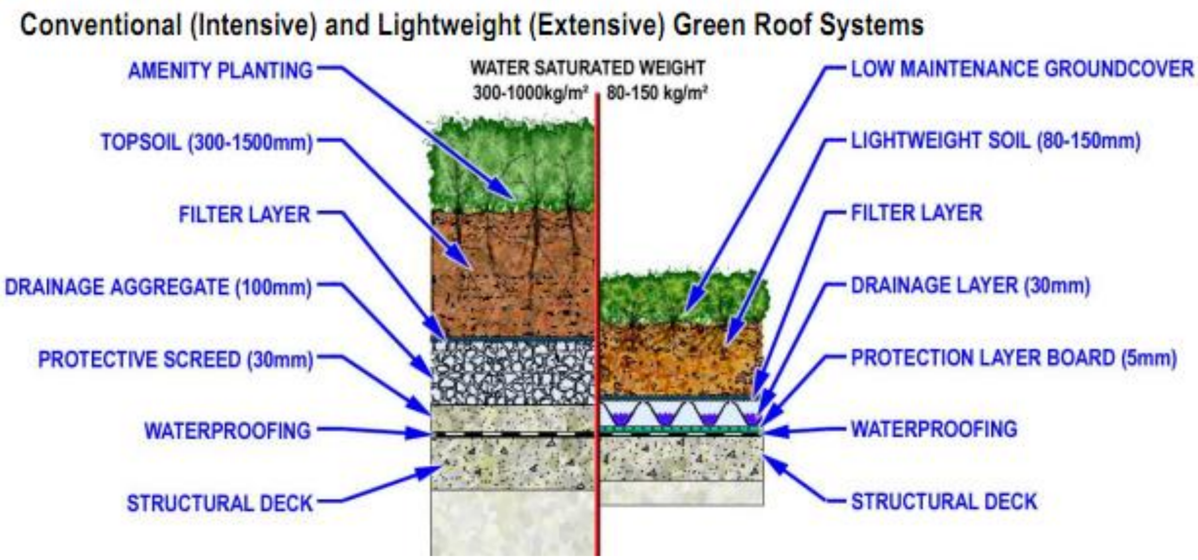


Figure A.1, Detail of extensive and intensive green roof, Source (Personal Achieve)

Appendix B: Study of Green Wall

Green wall

Eleftheria Alexandri and Phil Jones (2006) carried out the study which has been used them a two dimensional, prognostic, micro scale model, and expose the condition in nine cities with different climatic characteristics, three urban canyon geometries, two canyon orientations and two wind. Following figure shows the two-dimensional canyon model:

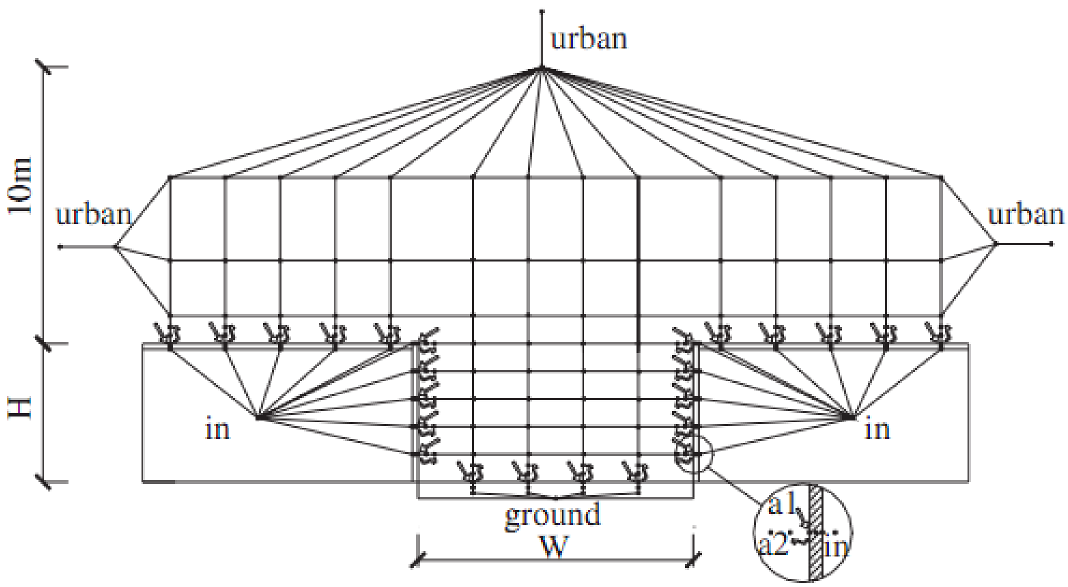


Figure B.1, Two-dimensional canyon mode, Source (Eleftheria Alexandri and Phil Jones, 2006)

So, effect of thermal performance of the roofs and green walls has been examined in both inside the canyon and also at the roof level. Following table shows the hydrothermal properties of plants, soil, building materials (concrete) and street material:

TableB.1, Hydrothermal properties of plants, soil, building materials (concrete) and street material, Source (Eleftheria Alexandri and Phil Jones, 2006)

Characteristic	Concrete	Asphalt	Soil	Plants
Specific thermal capacity (MJ/m^3K)	1.60	2.00	1.15	2.60
Thermal conductivity (W/mK)	1.70	1.30	—	—
Vapour diffusivity ($10^{-6}\ m^2/s$)	0.55	1.58	—	—
Ratio of vapour diffusion coefficient to total moisture diffusion coefficient	0.20	0.10	—	—
Emissivity	0.94	0.81	0.94	0.94
Albedo	0.23	0.10	0.23	0.30
Hydraulic conductivity ($10^{-4}\ m/s$)	—	—	0.01	—
Moisture potential, when soil is saturated (cm)	—	—	−49.0	—
Maximum volumetric water content (m^3/m^3)	—	—	0.492	—
Coefficient b	—	—	10.40	—
Convective heat resistance (s/m)	—	—	—	200
Resistance expressing the plant type (s/m)	—	—	—	100
Canopy extinction coefficient	—	—	—	1.4
Level of soil moisture below which permanent wilting of the plant occurs (m^3/m^3)	—	—	—	0.25

Green roofs and green walls can create better environment for outdoor space area and make the environment more human friendly also green roofs and green walls can have benefit for indoor thermal condition. So, it's better to add insulation layer to the building fabric, which it can reduce the cooling load demands inside the building.

The following calculation shows the internal thermal heat gain: Internal thermal gains, heat gains/losses (qE), building's fabric with an average U-value U, an indoors temperature Tin and an outdoors temperature Tout are given by the relationship; (Eleftheria Alexandri and Phil Jones, 2006)

qe = U (T (out) – T (in))

For the no green use [no gr], the cooling load for the non-vegetated canyon is given by the relationship; (Eleftheria Alexandri and Phil Jones, 2006)

qe (no gr) = U (T (no gr out) – T (in))

Eleftheria Alexandri and Phil Jones (2006) have been found that in hot and humid region the building with covering with different vegetation can decreased the urban temperature. It's also shown that air temperature will be decreased at roof level. Also shows that in Riyadh its reach up to 26.0°C maximum and 12.8°C day time averages, while inside the canyon decreases reach up to 11.3°C maximum and 9.1°C daytime averages. And especially Hong Kon shows that when both walls and roofs are covered with vegetation, the maximum temperature decreased up to 8.4°C.

Generally the larger amounts of solar radiation which covered vegetation surface will receive the larger its temperature decreases. For the low air velocities inside the canyon, the wind direction does not have any significant effect on temperature decreases due to Different vegetation. Green roofs and green walls can be effect by the urban geometry, the wider canyon is, and the weaker the effects of green roofs and green walls have on temperature decrease. Thus, for all kind of climate green walls have a stronger effect inside the canyon. But, green roofs have a stronger effect at roof level.

Therefore, the combination of both green roofs and green walls leads to the highest mitigation of temperatures inside the canyon. And by applying green roof and green wall especially in hot climates they could mitigate raised urban temperatures, which brings the temperatures down to more ''human-friendly'' levels and achieve energy saving for cooling buildings from 32% to 100%.

Appendix C: Study and Simulation of Solar Radiation and Construction

Solar Radiation

Solar radiation can be displayed for one or more objects in an Ecotect model. To reach to this step, after draw the building in Ecotect, for simulating it should load the climate data of specific city.

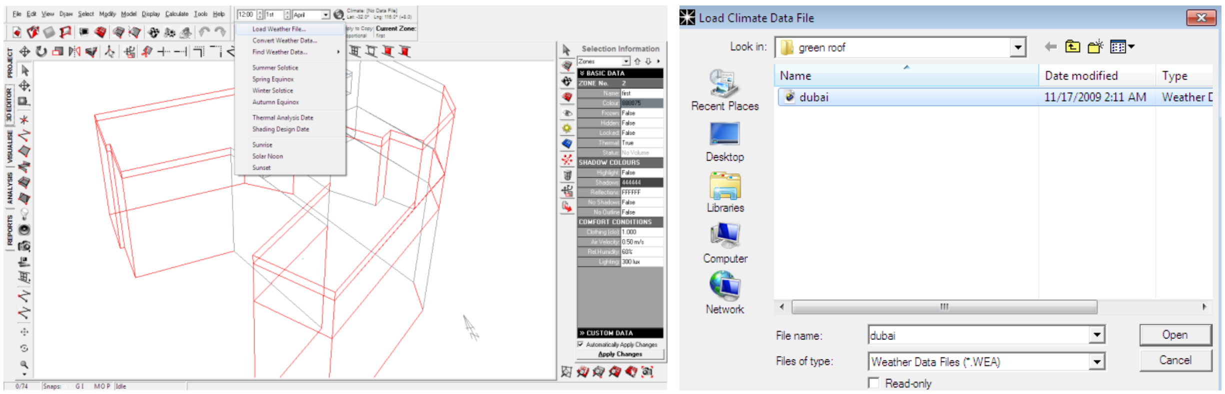
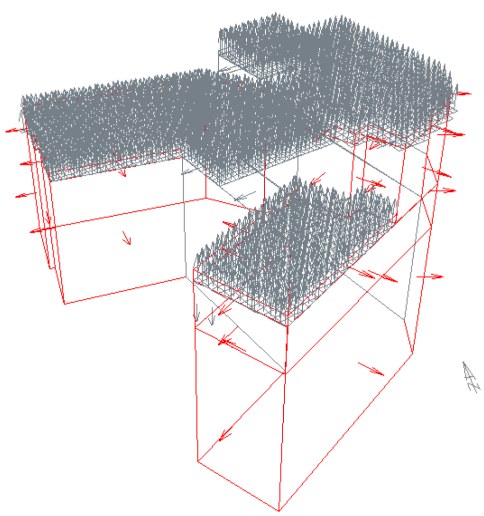


Figure C.1, Load the climate Data, Source (Ecotect)

Then by selecting the roofs can calculate the total solar radiation through the day, month and year. Since this research is yearly concerned for avoiding any mistake through the Ecotect, it's better to check all surfaces of the building and climate of year Fig C.2, C.3.



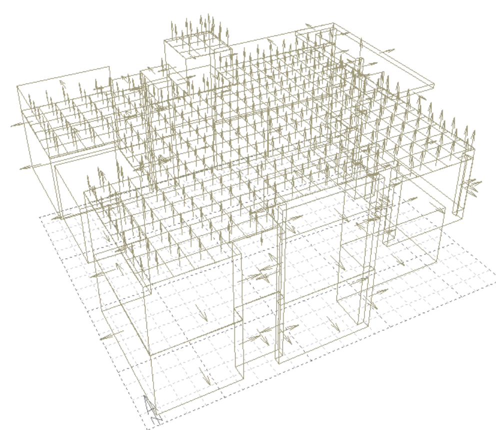


Figure C.2, C.3, All Surface and Selected the Roof area of both Building, Source (Ecotect)

By multiplying the number (total solar radiation, through Ecotect) of each building by the area of the each building roof and divided by the number of each total built area of a building can get the internal solar space. Later by apply the greenery on the roof the calculation will be change. Also by designing different green roof can get different solar radiation in to the internal spaces. And can easily control the cooling load and thermal performance of the building.

Construction Material

The software offers wide range of construction materials categorized into material assignments. The material assignments include: Void, Roof, Floor, Ceiling, Wall, Partition, Window, Panel, Door, Point, Speaker, Light, Appliance, Line, Solar collector and camera. Also these items subdivided into the other materials. Since this research is considered in roof, so it should test the different thickness of the roof, insulation and different R-Value. The construction materials of studied models are shown in following figure.

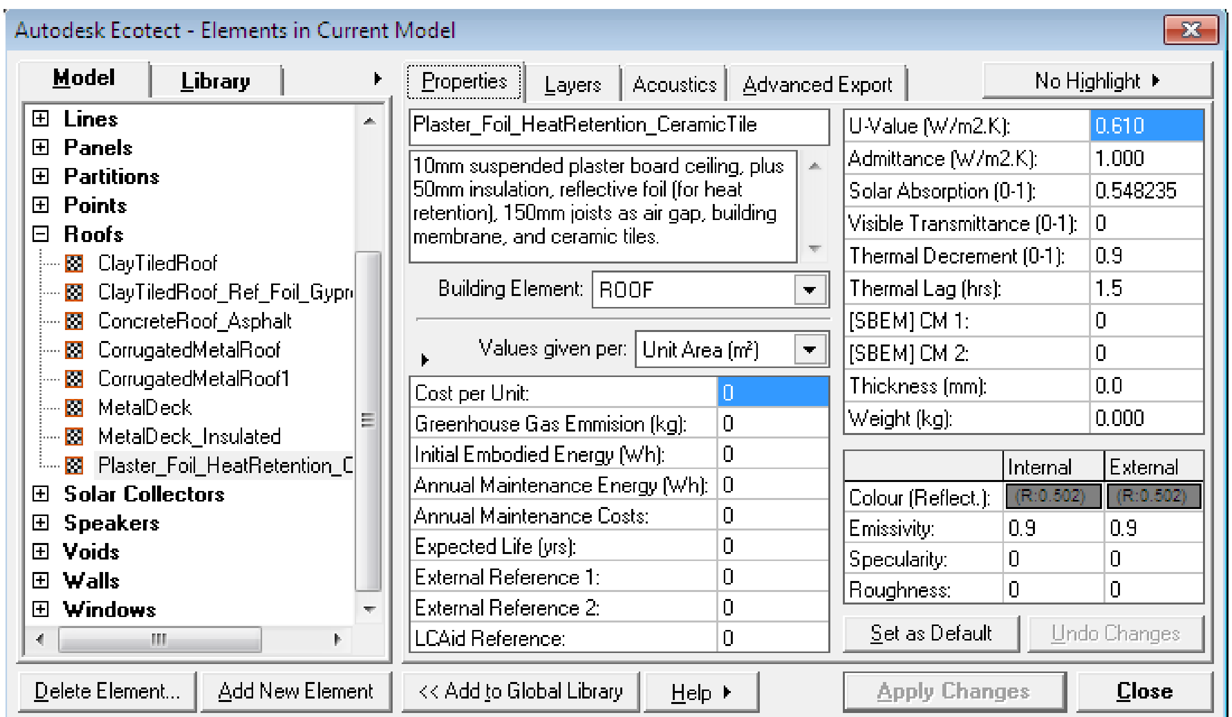


Figure C.4, The Construction Material of Roof, Source (Ecotect)

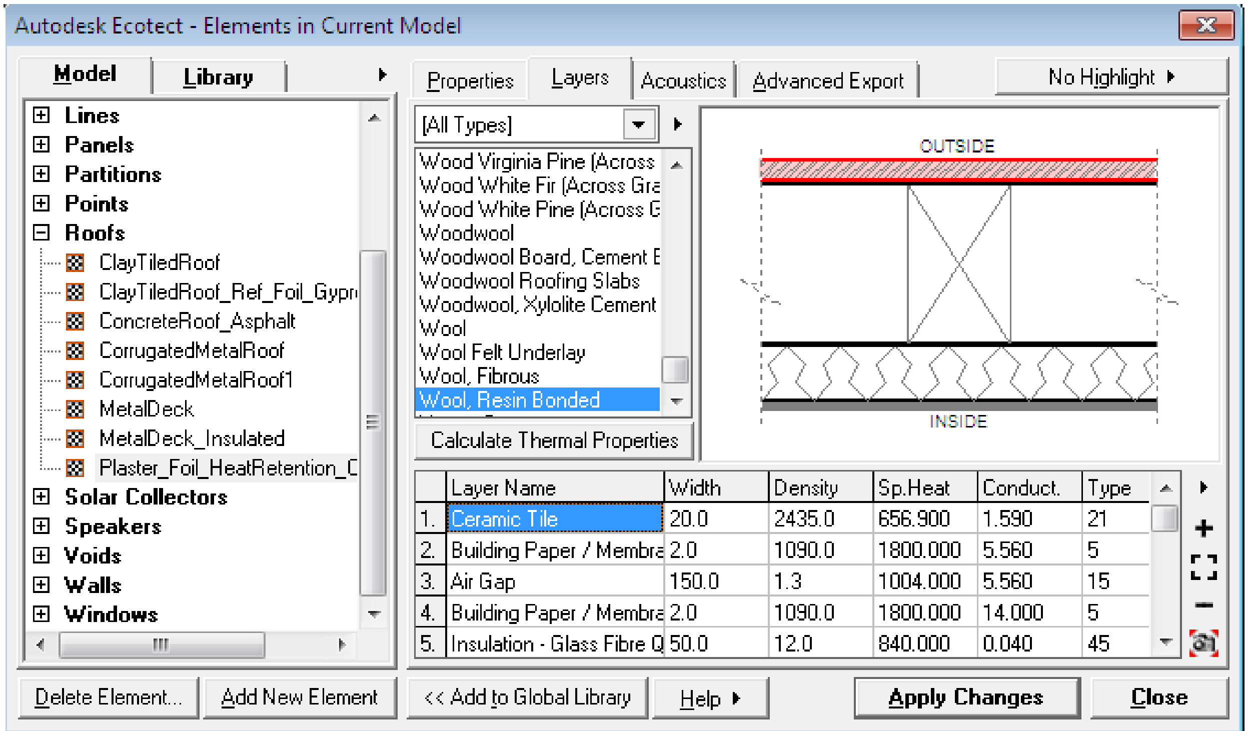


Figure C.5, The Construction Material of Roof, Source (Ecotect)

As it's shown in the figure it can easily change the material and thickness, even it can design new section of the roof. By applying the green roof these variable will be change and can get the best result from it.

Appendix D: Excel sheet of Calculation of Solar Radiation in Mid-rise Bilding and Villa (Ecotect)

Mid rise Winter, Summer, Whole Year (Conventional Roof, Green roof)
Villa Winter, Summer, Whole Year (Conventional Roof, Green roof)