

Evaluating The Energy Performance Of a Co-working Hub Based on Sustainable Roofing Method in a Warm Humid Climate

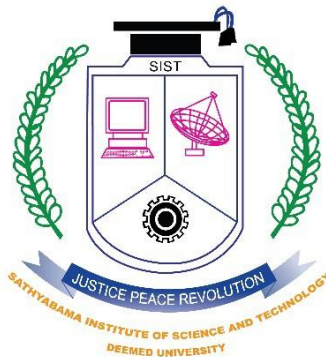
Thesis

Submitted in partial fulfillment of the requirements for the award of
Master of Architecture degree in Sustainable Architecture

By

SHALINI S (39890017)

DEPARTMENT OF ARCHITECTURE



SCHOOL OF BUILDING AND ENVIRONMENT

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119.

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BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **SHALINI S (3989001)** who carried out the Pre-Thesis entitled "**Energy efficiency through sustainable roofing system**" under our supervision from August 2020 to November 2020.

Internal Guide

(Ar. SHEETAL)

External Guide

(Ar.VIJENDRANATH)

(DR. DEVYANI GANGOPADHAY)

DEAN

SCHOOL OF BUILDING AND ENVIRONMENT

Submitted for Viva-voce Examination held on _____

External Examiner

DECLARATION

I **Shalini S (39890017)** hereby declare that the Pre-Thesis report entitled “**energy efficiency through sustainable roofing system**” is done by me under the guidance of **Ar. Sheetal** (Internal) and **Ar. Sukirtha suresh** (External) at **Sathyabama Institute of Science and Technology** is submitted in partial fulfilment of the requirements for the award of Master of Architecture degree in Building Management.

DATE:

PLACE:

SIGNATURE OF THE CANDIDATE

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ABSTRACT

Every building is compiled of roof and walls; the roof is undoubtedly the most exposed component of any building to the sun radiations and other climatic conditions. Using the most available component (i.e. Roof) as a bridge to reduce the gap between energy demand and sustainability. There is an increase in the number of countries that conduct green roof research in the last two decades realizing its importance globally.

Therefore, the aim of the paper is to use green roof/ living roof/ to reduce the energy demand in the building and saving its cost for a warm-humid region. The benefit of having a green roof is supportive to many other environment factors also; such as storm water management, mitigation of urban heat island, building value and aesthetics.

This paper will hence prove green roofs saves energy and energy cost in longer term, when compared to conventional roof system, considering the huge energy requirements in the future.

Key words:

green roof, save energy, reduce cost

ENERGY EFFECIENCY THROUGH SUSTAINABLE ROOFING SYSTEM

INTRODUCTION:

The basis of using green roofs can be trace back to the Ancient World around 500 B.C. The well-known green roofs were the Hanging Gardens of Babylon (Semiramis) and it was considers as one of the Seven wonders of the world, they were constructed over vaulted stone beams and waterproofed with layers of reeds and deep tar, Plants and trees was planted. This provides protection from the elements, good insulation during the winter months, and a cool location in the summer. Walls only receive about two-thirds of the maximum solar radiation that falls on the roof, and considerably less than this on the wall which faces away from the equator. The period of reception of direct solar radiation on walls is shorter than on roofs: east and west walls will only receive direct sunlight for half of the day. Undoubtedly the most critical part of the whole building surface is the roof.

AIM:

The main aim of the research is to explore sustainable roofing methods as a solution for reducing energy utilization and its cost utilization in a building.

OBJECTIVE:

- To Study the different types of roofing systems, such as green roofs, cool roofs ,filler slabs and conventional roof etc.
- To understand and analyse the factors that can reduce the consumption of energy in heating and cooling of the building.
- To evaluate the cost analysis the roofs.

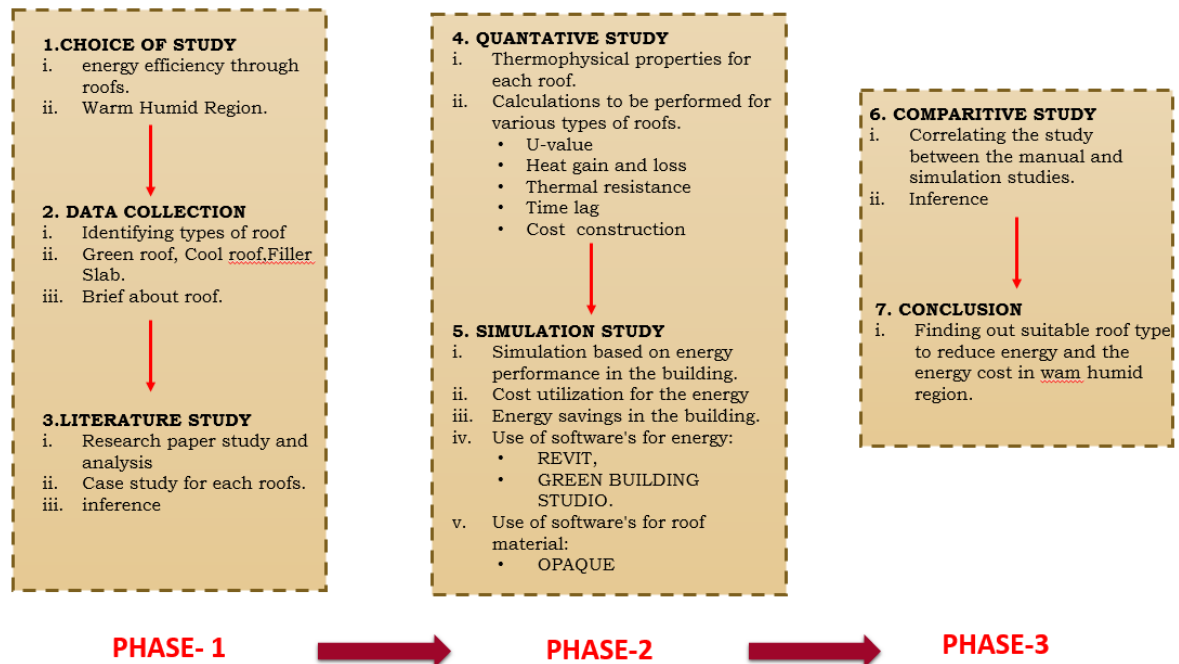
SCOPE:

- This study is focused on various benefits associated with green roof and research to promote green roofing technology as one of the sustainable approach.
- An approach to enhance the cooling performance of the building and its surroundings.
- The building value gets increased, aesthetically as well as economically and an opportunity to contribute to our environment.
- This study helps to understand the role of roof in making the building - energy saving, cost saving, as well as contribution towards to our ecology in mitigation of UHI and other factors.

LIMITATION:

- This study is comprised to the evaluation and creation of guidelines for the use of roofing systems for a **warm humid climatic zone**.
- The study is to deal with types of roof and its potential in contributing towards sustainability of building and environment.

METHODOLOGY:



Why do we need green roof ?

- Incorporating vegetation, growth medium and other landscape components on the rooftop of buildings offer several direct and indirect environmental benefits.
- According to a study conducted by the National Research Council of Canada, even a six-inch extensive green roof can reduce summer energy demands by more than 75 percent. By lowering air conditioning demand, green roofs decrease the production of associated air pollution and greenhouse gas emissions.
- An important benefit of green roofs is their ability to reduce and slow storm water runoff in urban environments. The ability a green roof has to absorb (and filter) water significantly lowers the risk of flash flooding and sewer overflows. Due to non-porous surfaces like pavement and rooftops, a typical city block generates more than five times more runoff than a woodland area of the same size.
- It is the need of the hour to reduce and sustain in the changing ecological conditions for the betterment of the future.
- Optimizing the possible ways to reduce the consumption of energy and cost of building.
- Green roof has both economical and ecological advantages, thus promoting its use in warm-humid region.

GREEN ROOF :

- A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. Green roofs are

also known as vegetative or eco-roofs. They fall into three main categories—extensive, intensive, and semi-intensive.

EXTENSIVE GREEN ROOF:

Roof has a shallow growing medium—usually less than six inches—with a modest roof load, limited plant diversity, minimal watering requirements, and is often not accessible.

INTENSIVE GREEN ROOF:

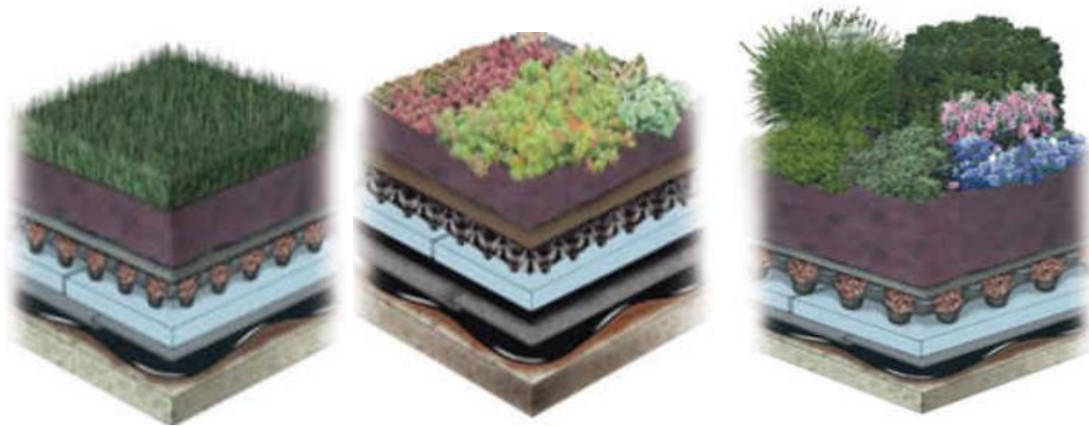
They have more soil and a deeper growing medium—sometimes several feet—that can support a more diverse plant selection, including small trees. Thus, they have more substantial structural loads and need more frequent maintenance and watering.

SEMI-INTENSIVE GREEN ROOF:

Roofs include features of both types. The appropriate depth of any green roof depends on the roof structure, the plants chosen, annual rainfall, and storm water performance requirements.

ADVANTAGES AND DISADVANTAGES IN TYPES OF GREEN ROOF

Comparison of extensive and intensive roofing systems			
	EXTENSIVE GREEN ROOF	SEMI INTENSIVE GREEN ROOF	INTENSIVE GREEN ROOF
Brief description	Thin soil, little or no irrigation, stressful conditions for plants	small herbaceous plants, ground covers, grasses and small shrubs, requiring moderate maintenance and occasional irrigation	Deep soil, irrigation system , more favorable conditions for plants
Advantages	- Lightweight - Suitable for large areas - Suitable for roofs with 0-30 degree slope - Low maintenance - Often no need for irrigation and drainage system - Relatively little technical expertise needed - Often suitable for retrofit projects - Can leave vegetation to develop spontaneously - Relatively inexpensive - Looks more natural - Easier for planning authority to demand green roofs be a conditions of planning approvals	- Green diversity of plants and habitats - Good insulation properties - More energy efficiency and storm water retention capability - Longer membrane life	- Greater diversity of plants and habitats - Good insulation properties - Can stimulate a wildlife garden on the ground - Can be made very attractive - Often visually accessible - Diverse utilization of roof (i.e. ,for recreation, growing food , as open space."
Disadvantages	- More limited choice of plants - Usually no access for recreation or other uses - Unattractive to some, especially in winter	- Greater weight loading on roof than extensive - Higher maintenance costs	- Greater weight loading on roof - Need for irrigation and drainage systems, hence , greater need for energy , water , materials , etc. - Higher cost - More complex systems and expertise required

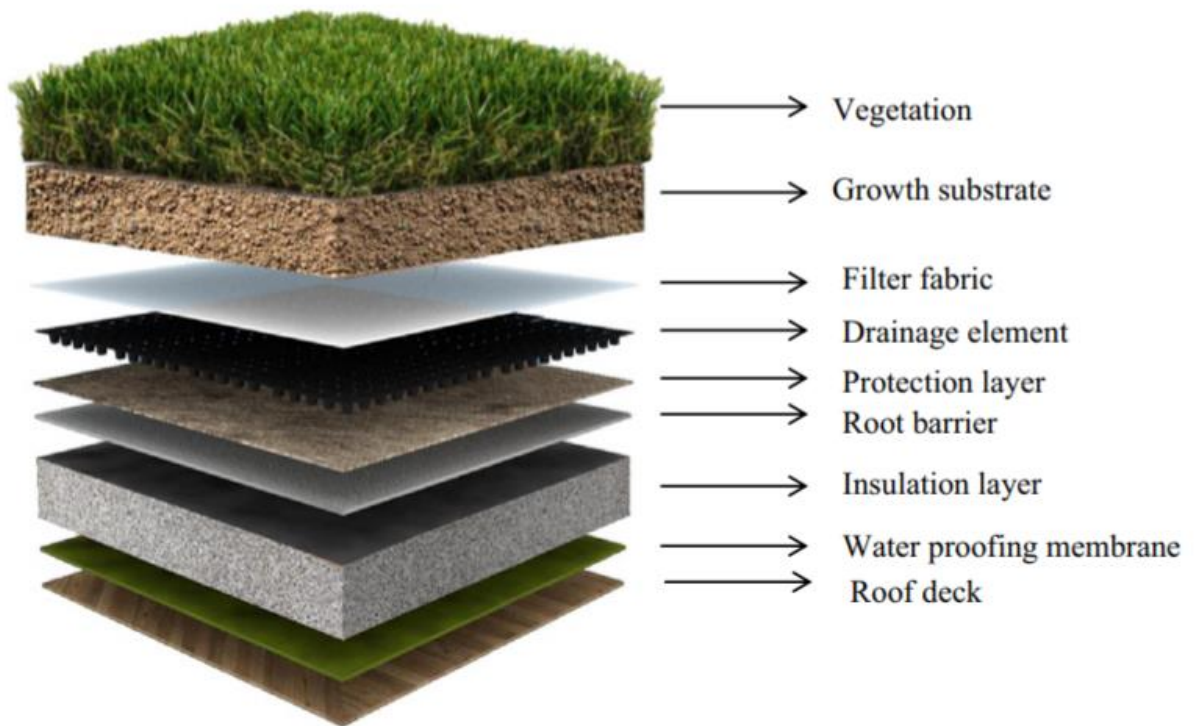


COMPONENTS OF GREEN ROOF:

The basic anatomy of a green roof consists of vegetation, growing medium, filter membrane, drainage layer, waterproof/root repellent layer, roofing membrane support for plantings above, thermal insulation, vapour control layer, and structural roof support. Each of these layers performs a specific function to keep the plants alive and to protect the structure beneath.

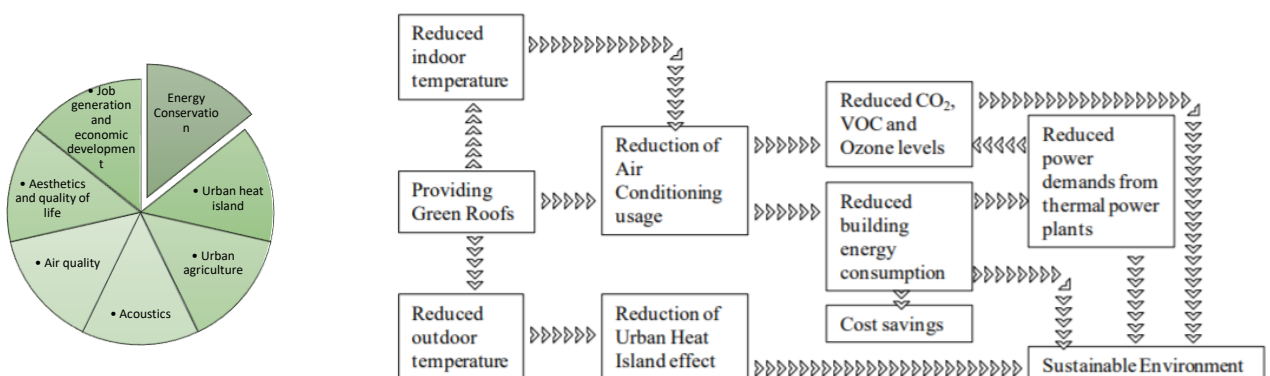
Installation process of green roof

- Install a monolithic type waterproof membrane such as rubber plastic on top of the roof decking.
- Place a 6mm sheet of plastic on the waterproof membrane and the waterproof will serve as root barrier.
- Top the first two layers with one or more thin sheets of three quarter inch foam insulation suited for contact with damp soil.
- Set a drainage mat which also called as a dimple mat with capillary spaces on top of the insulation .
- Frame the sides for the roof with me mesh gutter guards, wood or other edging that will permit drainage to hold soil in place and soil.
- Set plants in place, Water to settle soil around plants.



BENEFITS OF GREEN ROOF:

- The rapid runoff of **storm water** from paved areas and roofs contributes to destructive flooding, erosion, pollution, and habitat destruction.
- Economic benefits through the **reduction of energy costs** – saving money for energy that is consumed in cooling systems in summer and winter heating systems
- Reduced impact of extreme temperature values and **urban heat islands**. Absorbing the harmful effects of pollutants from air and improving the **quality of air**.
- The multiple layers of the vegetative roof protect the underlying roof- expanding **life span of roof**.
- New areas for rest, relaxation and interaction of residents, new habitat for flora and fauna, Improving the quality of life.

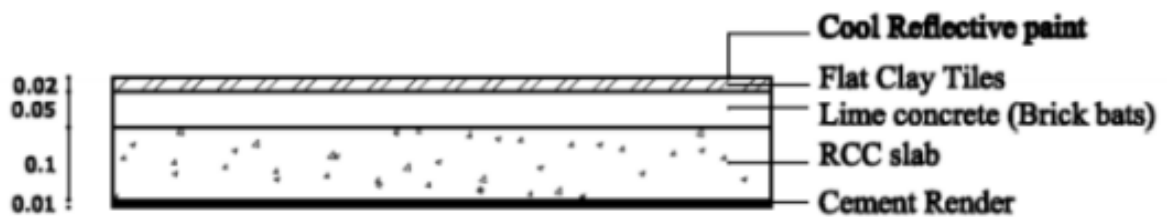


COOL ROOF:

- A cool roof is one that has been designed to reflect more sunlight and absorb less heat than a standard roof.
- Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles.
- The two basic characteristics that determine the "coolness" of a roof are solar reflectance (SR) and thermal emittance (TE).
- Both properties are rated on a scale from 0 to 1, where 1 is the most reflective or emissive.

Benefits of Cool Roofs:

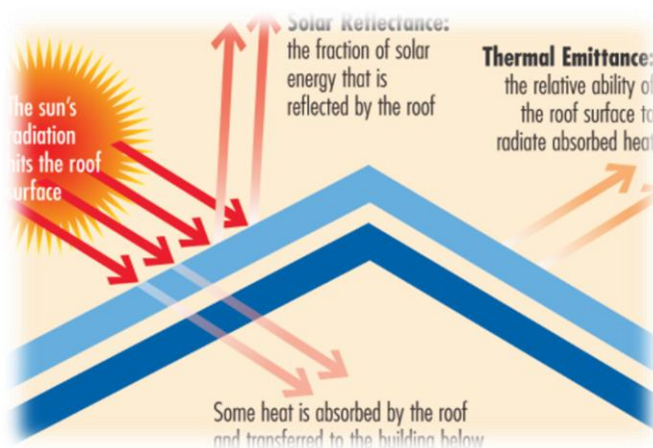
- Reducing energy bills by decreasing air conditioning needs.
- Improving indoor comfort for spaces that are not air conditioned, such as garages or covered patios .
- Decreasing roof temperature, which may extend roof service life.
- Reduce local air temperatures (sometimes referred to as the urban heat island effect)
- Lower peak electricity demand, which can help prevent power outages
- Reduce power plant emissions, including carbon dioxide, sulphur dioxide, nitrous oxides, and mercury, by reducing cooling energy use in buildings.



High solar reflectance (R_{sol}) lowers solar heat gain ($0.3 - 2.5 \mu m$)

High thermal emittance (E) enhances thermal radiative cooling ($4 - 80 \mu m$)

high solar reflectance + high thermal emittance = low surface temperature

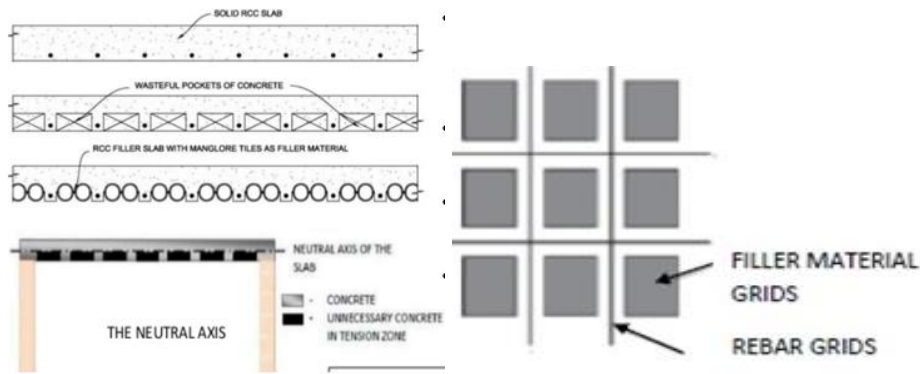


THERMAL PROPERTY:

Thermal properties of cool roof materials					
Material	Thermal conductivity (W/m-K)	Resistivity (K-m/W)	DENSITY (kg/m ³)	Specific heat (J/kg-k)	Emissivity
Reflective coating paint	0.72	0.02	1249	860	0.9
terracotta tile	0.798	0.01596	1890	880	0.97
lime concrete	0.73	0.059	1646	880	0.91
Reinforced Concrete	1.75	0.57	2400	840	0.94

FILLER SLAB:

- The filler slab is based on the principle for roofs which are simply supported.
- The upper part of the slab is subjected to compressive forces and the lower part of the slab experience tensile forces.
- Concrete is very good in withstanding compressive forces and steel bears the load due to tensile forces.
- Thus the lower tensile region of the slab does not need any concrete except for holding the steel reinforcements together.
- In a conventional rcc slab lot of concrete is wasted and it needs extra reinforcement due to added load of the concrete which can otherwise be replaced by low-cost and light weight filler materials.
- This will reduce the dead weight as well as the cost of the slab to 25% (as 40% less steel is used and 30% less concrete).
- This 'un-productive' concrete can be replaced by a '**filler**' **material** which will reduce the weight of the slab and also reduce the cost by reducing the amount of concrete used.
- The filler slabs also result in fewer loads getting transferred to the **load-bearing walls** and the **foundations**.
- The **air gap** in between the tiles makes it a **good heat insulator** and the **ceiling looks attractive** as well.
- The most popular filler material is the roofing tile. **mangalore tiles** are placed between steel ribs and concrete is poured into the gap to make a filler slab.



ADVANTAGES:

- Reduced weight of slab.
- **Passive solar cooling** where the **voids reduce the heat transfer and sound insulation**.
- Filler slab technology can also be applied to mass housing projects and township projects to **gain high cost saving** and also **saving in high energy consuming materials**.
- Filler slabs can be kept exposed (with proper workmanship) to **create aesthetically pleasing ceiling** with a view of filler material from below and thus the **cost of plastering** and/or painting also can be **avoided**.

Sustainable and environment friendly technologies and cooperating green building features.

BAKER'S STYLE

- one solution popularised by **laurie baker**, the pioneer architect of **cost effective** architecture in india, was to **place two numbers** of low grade **mangalore roof tiles** in between **the steel rods**.
- once the **centring is done**, the filler material is placed and then the **steel rods** tied as per the required spacing.
- since then, **architects and engineers** have placed everything possible under the sun, including **bottles**, computer **key boards**, **cement blocks**, **mud pots** and such others to achieve filler slabs.
- the criteria in selecting the material has largely been the cost and its looks.
- filler slab has crossed the boundary of research and controlled implementation to being one of the **regular options of construction** by **both government and private sector**.



RESEARCH PAPER 1 : Integration of green roof and solar photovoltaic systems

AIM:

- To study the benefits of integrating green roof and solar PV systems.

INTRODUCTION:

- Green roof and solar photovoltaic (PV) systems are two technologies that could contribute to sustainable building development and reduction of greenhouse gas emissions.
- when they are combined together on the building roof, the integration can enhance their functions and effectiveness by cooling and shading effects .
- It is believed that cooling from evapotranspiration of green roof plants enables a higher efficiency of PV panels, and at the same time, the panels shade the plants from excessive sun exposure and evaporation thus improving plant growth.

METHODOLOGY:

- The thermal properties of green roofs, the electrical efficiency of PV panels and the typical arrangement of system integration are described.

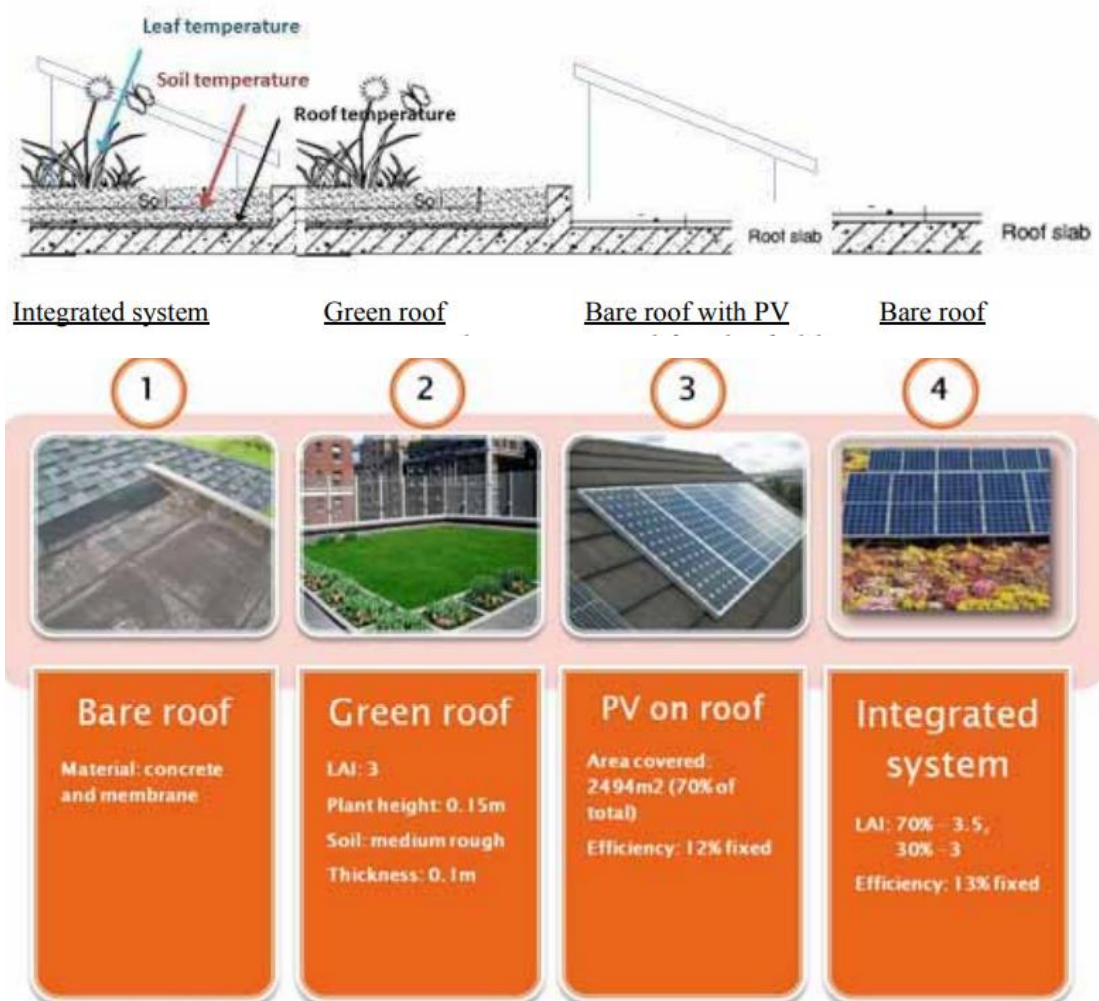
SYSTEM INTEGRATION:

- The green roof cools ambient temperatures around the solar panels, allowing the solar panels to stay cooler and function better.
- Green roof can help reduce dust level and improve air quality, the efficiency of PV system could be enhanced but no solid evidence can be found in the literature at present.

ENERGY SIMULATION ANALYSIS:

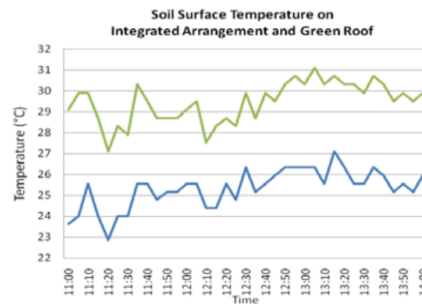
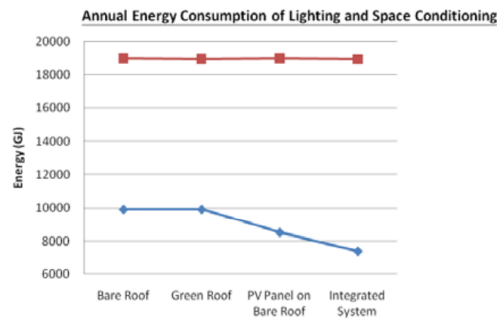
- To investigate the energy impacts of green roof and solar PV integration, a building energy simulation software, EnergyPlus Version 6.0 (www.energyplus.gov), was used.
- EnergyPlus has a green roof model developed by Sailor (2008) and can calculate the annual energy consumption of the whole building with solar PV systems.
- Four simulation models were set up using EnergyPlus for comparing the energy performance of green roof, PV and the integrated systems under the Hong Kong climate

- A 12-storey office building with a total floor area of 46,320 m². Model number 2, 3 and 4 are derived from the base case with green roof and PV systems added.
- It is assumed that the PV systems of model number 3 and 4 have efficiency of 12% and 13%, respectively.
- Each PV system covers a roof area of 2,494 m².
- The leaf area index (LAI) of model number 2 is assumed to be 3 for a typical extensive green roof, whereas the LAI of model number 4 is divided into two parts: LAI = 3 for 30% of roof area (exposed) and LAI = 3.5 for 70% of roof area (under the PV panels).
- The power generated from the PV system is used for general lighting (i.e. decreases the actual lighting energy use).



Annual Energy Consumption:

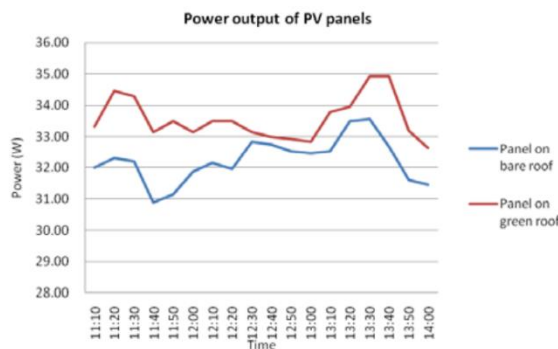
The PV system will only affect the lighting energy and the green roof system will affect the building thermal load, it is more effective to assess the energy consumption components of lighting and space conditioning in order to evaluate the energy impacts.



- The monthly energy generation of the stand-alone PV (model number 3) and green roof integrated PV system (model number 4).
- It can be seen that the PV systems generate more energy during summer time than winter time due to high value of solar irradiance in summer.
- For each calendar month, the integrated system produces 8.3% more energy than the stand-alone system because of the efficiency improvement (assumed from 12% to 13%).

Assessment of PV Output:

- The average power production over the period for integrated system and bare roof PV panel are 32.2W and 33.6W, respectively.
- In general, the integrated system can give about 4.3% more electricity than the PV on bare roof during measurement period.
- The temperature evaluation of the PV panels also indicated that the cooling effect by vegetation is quite significant.



- The building is the headquarters of the Electrical and Mechanical Services Department (EMSD) and has a roof area of about 7,900 m².
- The roof is made of aluminum sheet modules (known as Kalzip aluminum standing seam roofing system) and a 350 kW grid-connected PV system has been installed on the rooftop.
- Assuming the green roof will be installed on 80% of the roof area, by applying the energy saving indicator, the annual energy and cost saving is calculated.

Table 1. Green roof performance calculation

Green roof area	6300 m ² (about 80% total roof area)
Energy saving per green roof area	37.32MJ/m ² (based on simulation result)
Energy saving due to green roof installation	235,116 MJ
Electricity consumption reduction	65,310 kWh
Annual cost saving	<u>HK\$63,351</u>

Assuming the PV system efficiency improves from 12% to 13% due to cooling effect of the green roof. Additional electricity generated from the PV system and the cost saving are calculated as shown in Table 2. The electricity cost is assumed to be HK\$0.97 per kWh.

Table 2. PV system performance calculation

Parameter	With Green Roof (Efficiency = 13%)	Without Green Roof (Efficiency = 12%)
Annual final yield (kWh/kWp)	1,021.6	943
Electricity generated (kWh)	357,560	330,050
Cost saving (HK\$)	346,833	320,149
Annual cost saving due to green roof :	<u>HK\$26,685</u>	

CONCLUSIONS:

- Integrating green roofs and solar PV systems can enhance their functions and effectiveness by cooling and shading effects.
- The results of literature theoretical study, field measurements and case study in Hong Kong indicated a positive influence for this integration.
- It is found from field measurements that green roof surface and soil temperatures are reduced from the PV panel shading and higher power output of PV panel is achieved from the green roof cooling effect.
- The findings of year-round building energy simulation using EnergyPlus indicated that the energy consumption for air conditioning of the integrated system is slightly lower than the stand-alone system and the PV system on integrated approach generates 8.3% more electricity than the stand-a-lone option.