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THE EFFECT OF HYDROPONICS PLANTED ROOF ON THE THERMAL PERFORMANCE OF RESIDENTIAL BUILDINGS IN EGYPT

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Abstract

The international need towards increasing environmentally friendly buildings with less energy consumption and water wastage has led many countries to adopt the trend of building green roofs. This study is dedicated to investigating how to improvement the thermal performance of existed Egyptian residential buildings, by finding an alternative for regular green roofs, as existed Egyptian residential buildings cannot support regular green roofing loads because, it requires approximately 400 kg/m² for 10cm in depth soil thickness and the Egyptian roofs have been designed to withhold a cover load of 200 kg/m², the recommended solution should address Egyptian government major problems in energy consumption sector and water shortage sector. The primary goal of this research is to investigate the intensity of total solar radiation affecting the building's conventional external roof surfaces before it enters the building's internal space, affect it, and compare it with intensity of total solar radiation with the presence of hydroponic roof. The study showed that the use of hydroponic roof would enable planting leafy agriculture that is 90% less reliant on water irrigation plus, the total solar radiation decreased throughout the whole year with approximately 69% and energy consumption with approximately11.93 %.

KEYWORDS: Green Roof, Hydroponic Roof, Sustainability, Thermal Performance

1. INTRODUCTION

The history of the green roofs has beyond doubt proved that it would lead to a significant decrease in the urban heat island effect caused by the rapid replacement of the naturally present vegetation with concrete buildings, altering the thermal characteristics of the aforementioned. On that account, environmentally friendly buildings with improved thermal performance in comparison to the concrete ones would not only save the environment but would save us energy as well. However, as discussed before, the residential Egyptian buildings would need an alternative due to technical concerns which brings us to the aim of this research. This research paper is dedicated to investigating the means and effects of hydroponic planted roofs on the thermal performance of architectural space.

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2. LITRETURE REVIEW

2.1. Green Roof background

2.1.1. Old Green Roof

Green roofs and roof gardens date back thousands of years. Despite the existence of rooftop gardens has been reported, little evidence has reached us [1], but history reveals that the purpose of green surfaces was multifaceted. These Purposes include insulation properties and escape from urban stress on the environment. In cold climates, green surfaces increase indoor thermal storage and help them keep heat. In hot climate they help kept heat outside the building [2]. Early proofs of the roof gardens are the mausoleums of Augustus and Hadrian, see figure (1). It is well known that the Romans are known to have planted trees in many institutional buildings. The ancient historian Pliny wrote about the importation of trees to these gardens on the roof.

Figure 1. The Mausoleum of Augustus in 2016 before restoration [33]

2.1.2. Modern Green Roof

The Germany industry is known of being the pioneer for modern-day green roof systems they used flammable tar for inexpensive roof housing, a Constructer named H. Koch wanted to reduce the fire hazard by adding a sand and gravel which functioned as water proofing and protection. Consistently and new area of industry showed up to for fill the market demands from material suppliers, roofing professionals, installers, and maintenance crews. In Germany, Norway, Austria, France, Switzerland and other European countries, green roofs have become a commonly accepted feature in the construction industry and urban landscape [2].

2.1.3. Green Roofs Definition

Green roofs developments involve creating a green space above a human -made structure. Green Roofs are applied as another layer of the roofing system. As shown in figure (2), this layer includes Roof Structure, Waterproofing membrane, Drainage system, Specialized growing medium and Vegetation [3].

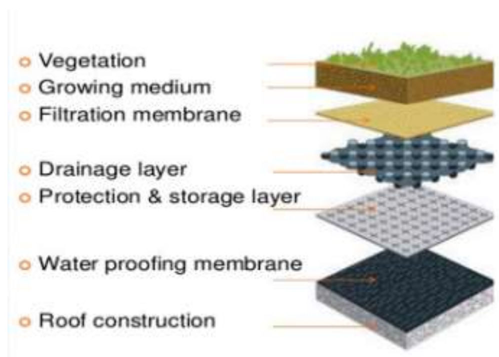


Figure 2. Green Roof Layer system [26]

2.2. Green Roof General Benefits

2.2.1. Air Quality

Urban areas have pollution. When concrete, stones, glass, and asphalt are heated from the sun, air will then be heated up leading to vertical air movements carried with dirt and dust however, vegetation preferred to be local plants as Aloe Vera, Agave, Grasses, columbines, asters, and Black eyed Susan..etc, will decrease the amount of heat transferred to air landing to a smaller number of particles to be carried by air as it will decrease thermal air movement. These particles which are trapped in leaves and soil will be washed out by rains into soil and growing medium of the plants they also, absorbed gaseous pollutants through photosynthesis and

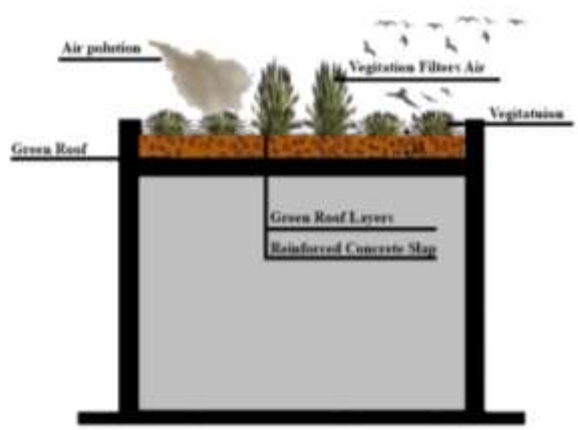


Figure 3.Sketch shows that vegetation decreases air pollution (Author)

sequester them in their leaves (which fall to the ground in autumn to create humus) [4] [5], as illustrated in figure (3).

2.2.2. Carbon Dioxide and Oxygen Exchange

Plants are important for the survival of life on earth. As photosynthesis which occurs in green leaves and steams, convert carbon dioxide, water, and sunlight (solar radiation) into oxygen and glucose, see figure (4). Plants give us and other creature's oxygen, food and in return, we produce carbon dioxide and manure which plants need for survival. Studies concluded that every single mature Beech Tree (80-100 years old). With crown diameter of 15m, shades 170 m^2 of surface area, has a combined leaf surface of $1,600m^2$, and creates 1.71 kg oxygen and 1.6 kg of glucose every hour (Using 2.4 kg of carbon dioxide, ninety-six liters of water and 25.5 kilo joules of heat energy). This oxygen production equals intake of 10 humans every hour [4] [6].

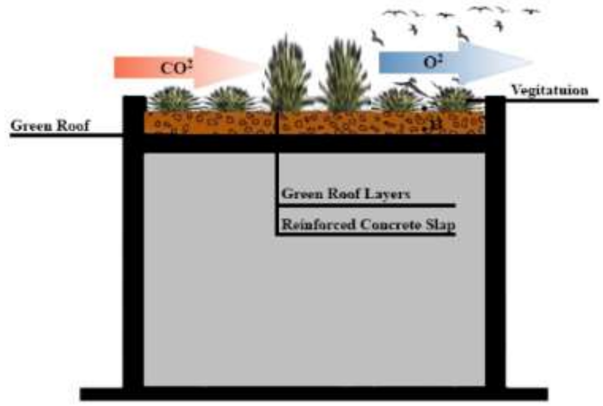


Figure 4.Sketch shows that vegetation Convert Carbon dioxide to Oxygen (Author)

2.2.3. Green roof thermal benefits

A Study Conducted at the University of Kobe, Japan, that green roof was the better to achieve reduction in heat flow from the outside to the inside of the building out of four separate roof therapies. The roofs had different albedo a high albedo value means more reflected light and less absorption. Green roof planted with grass had the lowest albedo and reduced heat flow in the building effectively [7],see graph in figure (5) and (6).

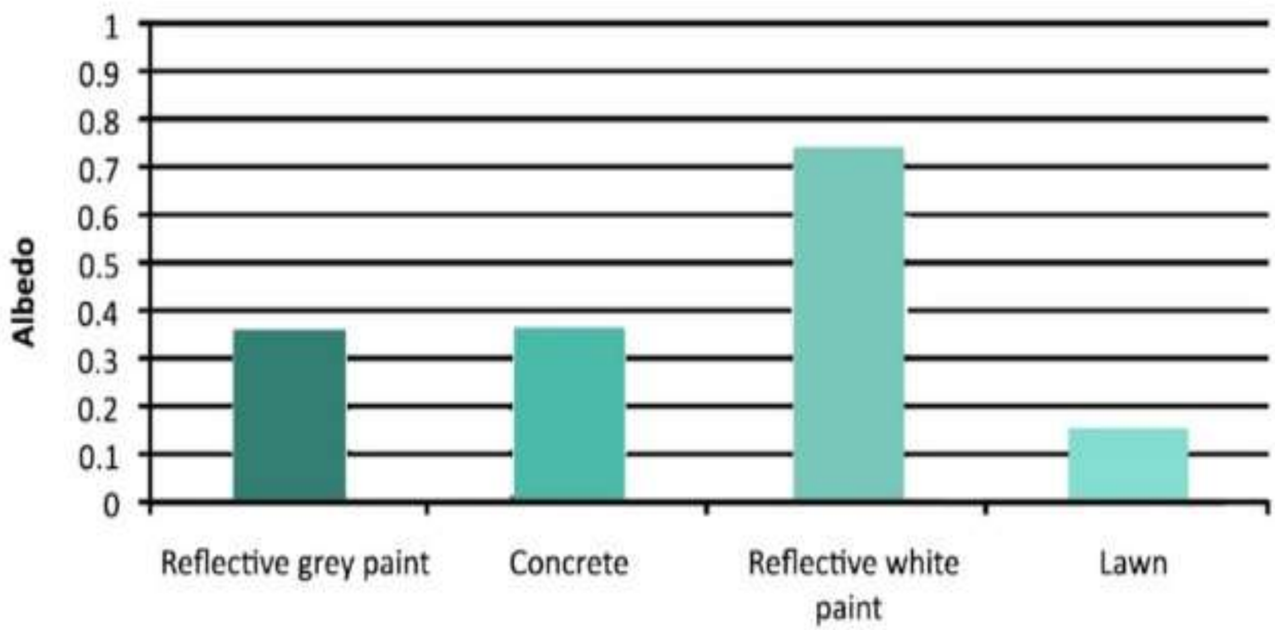


Figure 5 : Sensitive flux under various roof and albedo treatments (ability to reflect solar radiation) [8]

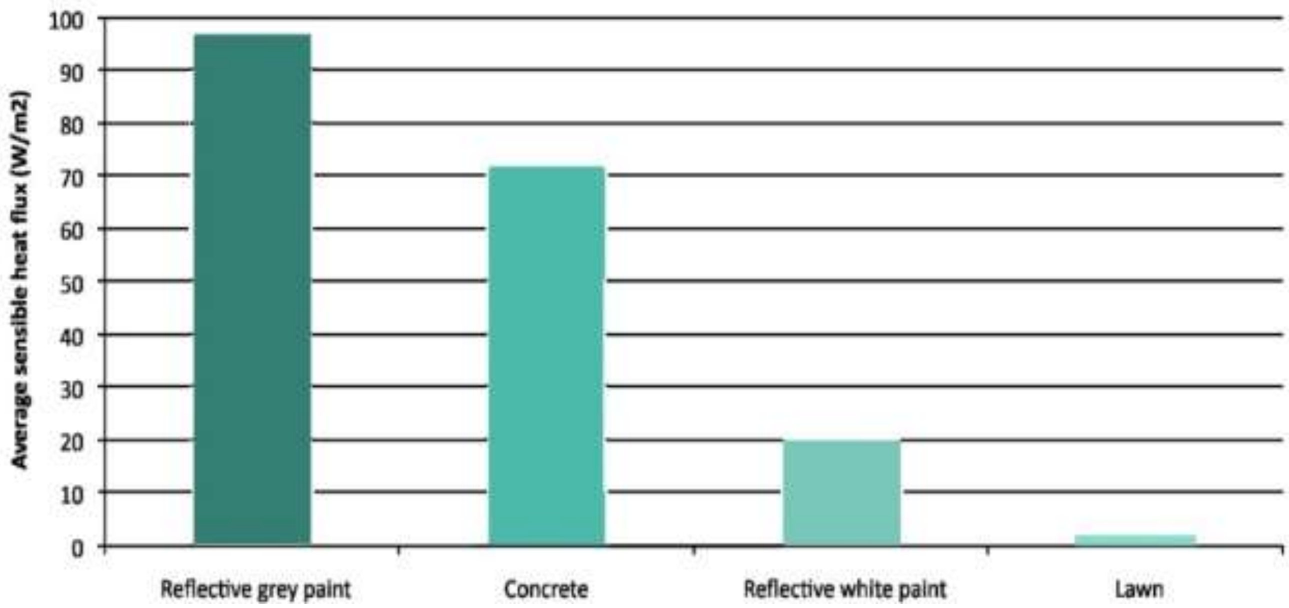


Figure 6 : Sensitive flux under various roof and albedo treatments (ability to reflect solar radiation) [8]

A comparison between two models, the one without insulated bare roof and a green roof, the green roof offers considerable cooling advantages, while insulation under the concrete roof has the greatest impact. The comparisons in the shown graphs in figures (7) and (8), that green roofs can help to reduce the thermal behavior, around the roof, on poorly insulated houses [7].

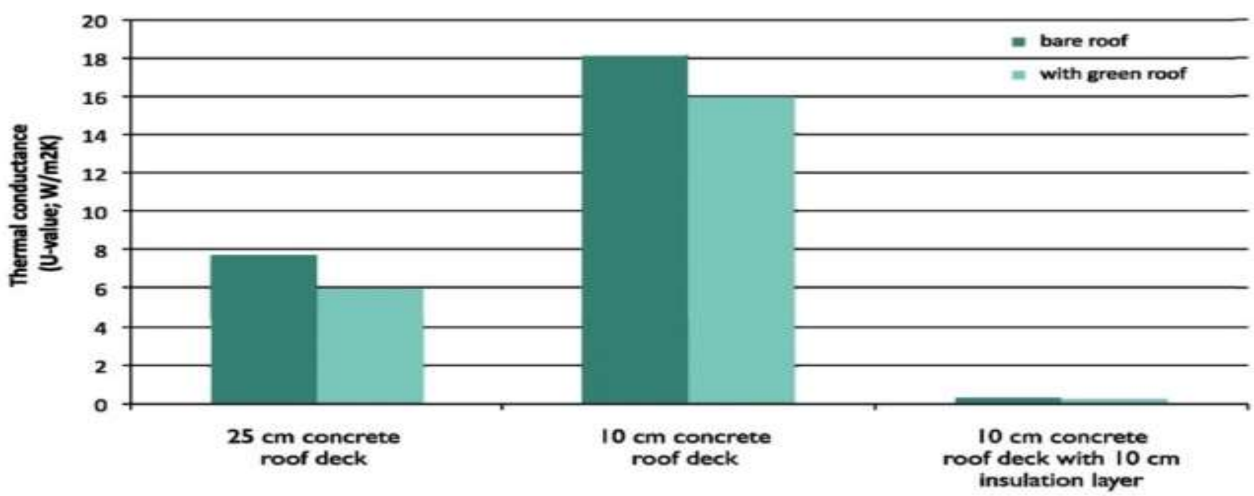


Figure 7 : Effect of a green roof on heat transfer (thermal conductance) modeled for diverse types of roof construction [9]

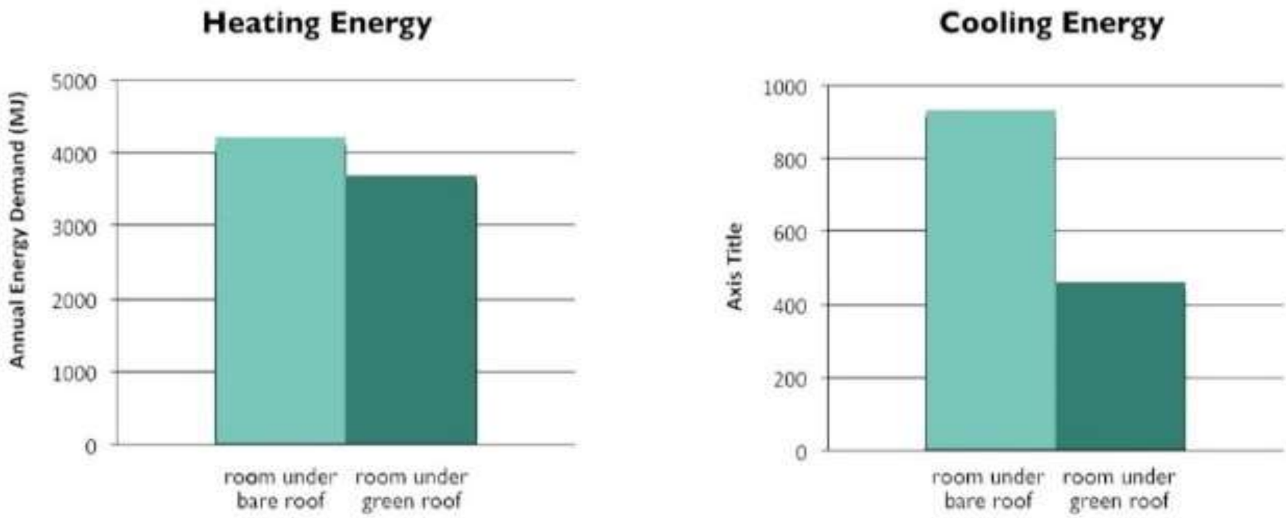


Figure 8 : Heating and Cooling Energy demand under bare roof and green roof [10]

2.2. HYDROPONICS

2.2.1. Hydroponics Background

Since many years ago, Hydroponics is a method of food production used by various civilization, it dates to (605 - 562 BC) In Babylon, the Euphrates River has watered vegetation on the terraces. The Aztecs used a system called 'chinampas' at Tenochtitlan around 40 B.C.; they are man-made islands that are floating over the water and its roots indirect contact with the water [11]. The main principles for planting using soilless culture were developed by researchers named Dr. W.F. Gericke and Dr. Hoagland. In 1930s, they published a series of papers in planting using soilless culture [12].

During the Second World War, the US Army set up a massive hydroponic garden in many western Pacific islands to provide the troops running in this region with fresh vegetables. The hydroponic technology has been a major commercial element for vegetables and flora since the 1980s. And by 1995 more than 60,000 acres are planted in hydroponic greenhouse crops worldwide, a land is predicted to develop further [13].

2.2.2. Hydroponic Definition

Hydroponic was defined in the Fourth Edition, 1999, of Webster's New World College Dictionary as Science of cultivation or plant culture in nutrient-rich or humid inert materials, instead of soil. The Random House Webster's College Dictionary, 1999, defines it as the culture of growing plants by Position the roots instead of the soil in liquid nutrient solutions [14]. Hydroponic was defines as a method for growing plants in nutrient solution (water has fertilizers), with or without usage in mechanical support of an artificial medium such as sand, gravel, vermiculite, rockwool, perlite, peat moss, coir, or sawdust…. etc. [15], see figure (9).

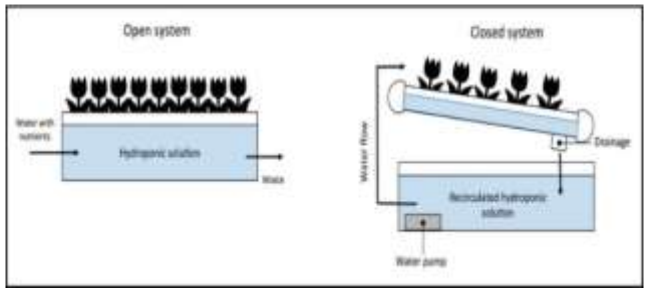


Figure 9. hydroponic open system and closed system [36]

2.2.3. Hydroponics Advantages and Disadvantages

2.2.3.1. Advantages

- Crops can be cultivated if there is no proper soil, or the land is polluted by illness.
- Labor needed to level, cultivate, fumigate, water, and other customary operations is highly decreased. [16]
- Maximum output is achieved so that in high-density and costly land locations the system is economically achievable. [16]
- This can reduce land and stream contamination [16]
- The plant can simply access all the provided nutrients.
- Lower nutrient amounts may be used. [17]
- The pH of the fluid is manageable to guarantee the best absorption of nutrients. [17]
- No nutritional losses due to leaching and vaporization. [17]
- More environmental management is usually a system feature (i.e., root environment, prompt nutrient feeding or irrigation), Light, temperature, humidity and air composition can be adjusted though the operations. [16]
- A hydroponic system may also be adapted for household and patio gardens in high-rise buildings by an amateur horticulturalist (Is the person who practice hydroponics). [16]

2.2.3.2. Disadvantages

- The growth operation should be led by trained employees. It is crucial to be aware of how plants develop and the nutritional principles. [16]
- Soil diseases and parasites that have been introduced may rapidly spread to all beds in the same closed system nutrient tank. [16]
- Research and development are needed for the most accessible plant species suitable to regulated growth circumstances. [16]
- The plant reacts amazingly quickly to excellent or low nutrition. Every day, the grower must check the plants. [16]
- There can be an anoxic state that prevents ion absorption of oxygen decreased in nutrient solution. [17]

3. Research Method and Materials

The aim of the study is to compare thermal performance of conventional roof and hydroponic roof as to see the effect of hydroponic roof on the thermal performance of buildings in Alexandria, Egypt. Firstly, we need to understand and analyze Alexandria, Egypt's weather data. Then a computerized model should be made for both roofs and analyze it by introducing correct date to the software to obtain the best results out of the simulation program however, this needs a good knowledge of the software and skill. Then understand the buildings material and its physical properties to correctly input its data. After words, the simulation process should take place by modeling the building and input all the necessary data and finally compare the results.

This research is being conducted with the help of simulation program, Ecotect from Autodesk. An important analysis tool with a wide variety of simulation and analytical capabilities through use of desktop and online service platform, the main approaches for computing and showing data in Ecotect are the analysis Grid (of points), analysis Surfaces and the thermal Analysis of Zones.

It is mostly recommended to use local plants and for hydroponics it is preferred to be leafy plants such as lettuce, Watercress, parsley, Basil, Mint ... etc. In our case Batavia lettuce is used. Batavia lettuce is a type of lettuce that belongs to the Asteraceae family, of the sativa specie. Batavia in seeding period needs direct sun light ranger from 12 to 16 hours daily, while during growing to harvest needs. lumens Approximately 80-100k will be adequate, too much than that (150-200k) may cause lettuce to flower (due to the heat concentration) with time period ranges from 4 to 8 hours a day. Timing: From sowing to planting out: 3-5 weeks depending on the season and the weather. From planting to harvesting: 4-6 weeks.

3.1. Climate in Alexandria,Egypt

Egypt is mostly characterized by a hot desert environment (Köppen climate classification BWh). The climate is typically extremely dry across the nation, except for the northern Mediterranean coast, which receives winter rainfall. In addition to the little of rain, Egypt has a general climatic feature of high heat throughout the summer months, while midday temperatures are moderate in the north coast. [18] [19] Average low temperatures range from 9.5 °C (49.1 °F) in winter to 23 °C (73.4 °F) in summer, with average high temperatures ranging from 17 °C (62.6 °F) in winter to 32 °C (89.6 °F) in summer. [18] [19]. Temperatures are tempered at the beaches, but the situation changes in the interior, which is away from the moderating northerly breezes. The length of sunshine is high across Alexandria, Egypt, ranging from a low of 3,300 hours along the northernmost half in areas like Alexandria to a high of over 4,000 hours deeper in the interior, throughout most of the nation [18] [19].

3.1.1. Solar Radiation

The sun chart diagram Generated by simulation program Ecotect from Autodesk 2011 for this building in Alexandria, Egypt, its best orientation for solar radiation may be decided as the simplest orientation for the building were the short facades face east and west, which is 195 degrees from North where short facade should face Northwest – East South see figure (10).

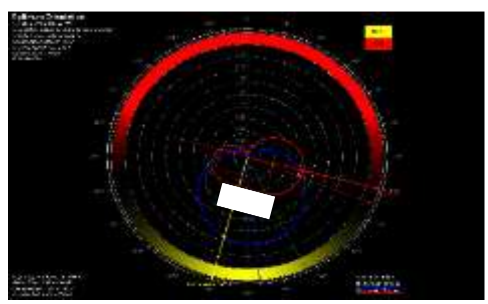


Figure 10. Best Building Orientation, Generated by simulation program Ecotect from Autodesk 2011 [20]

3.1.2. Psychometric Chart

The psychometric charts Generated by simulation program Ecotect from Autodesk 2011 show the relation between dry bulb temperature and relative humidity in Alexandria, Egypt to decide the most pleasant condition for the space. The thermal comfort zone is decided by temperature and relative humidity, as well as the occupant's involvements such as clothing and activity level. Alexandria often has a relative humid and wintry weather in winter but, in summer the weather is humid and hot, see figure (11).

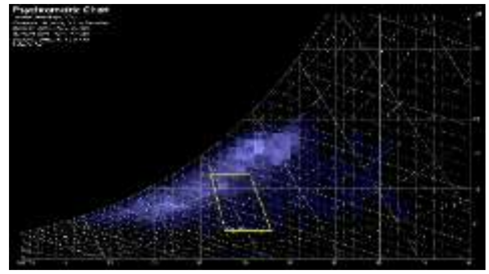


Figure 11. Psychometric charts for Alexandria during winter, Generated by simulation program Ecotect from Autodesk 2011 [20]

3.1.3. Alexandria Climate Analyzing

Alexandria climate Generated by simulation program Ecotect from Autodesk 2011 is shown in figure (12), below. according to the graph, Alexandria temperature gradually increases from middle of March and reaches its peak in August, then starts do decrease gradually were at this period air conditioning is needed.

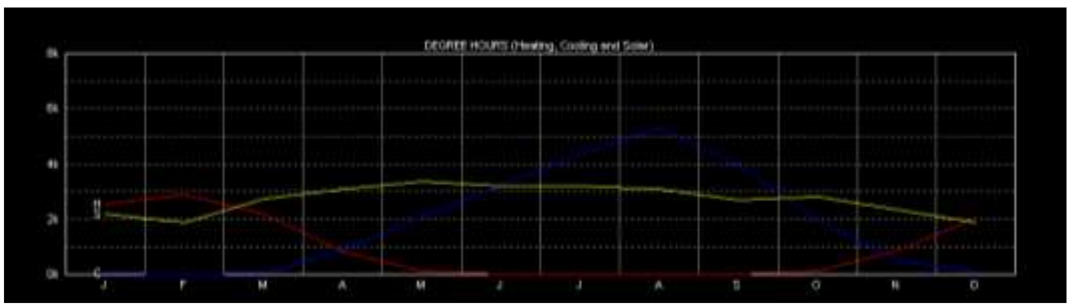


Figure 12 : Alexandria Climate analysis, Generated by simulation program Ecotect from Autodesk 2011 [20]

3.2. Model

The building is placed in Alexandria Egypt, with a total floor area of approximately 219.3 square meter and 3-meter height of total volume 658 cubic meter however, the parapet height is 1 meter. Total openings area is approximately 26.5 square meter. Hydroponic roof was added to conventional roof with a total floor area of approximately 155 square meters and height of 0.3 meter to have a total volume of approximately 46.5 cubic meter which is approximately 70 % of the total conventional roof floor area, as illustrated in figures (13) and (14).

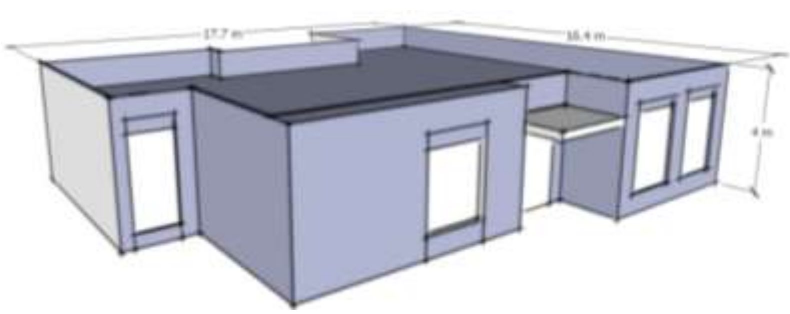


Figure 13.Sketch illustrating Building and its dimensions.

In general, healthy vegetation is a very good absorber of electromagnetic energy in the visible region. Chlorophyll strongly absorbs light at wavelengths around 0.45 (blue) and 0.67 µm (red) and reflects strongly in green light, therefore our eyes perceive healthy vegetation as green. Healthy plants have a high reflectance in the near-infrared between 0.7 and 1.3 µm. This is primarily due to the internal structure of plant leaves [21] most fresh leaves have a specific capacity comparable to that of water (4.2 J/kg ℃) and varies with the plant species. The leaf specific heat capacity depends on the water content, fibre content, and other organic constituents [22].

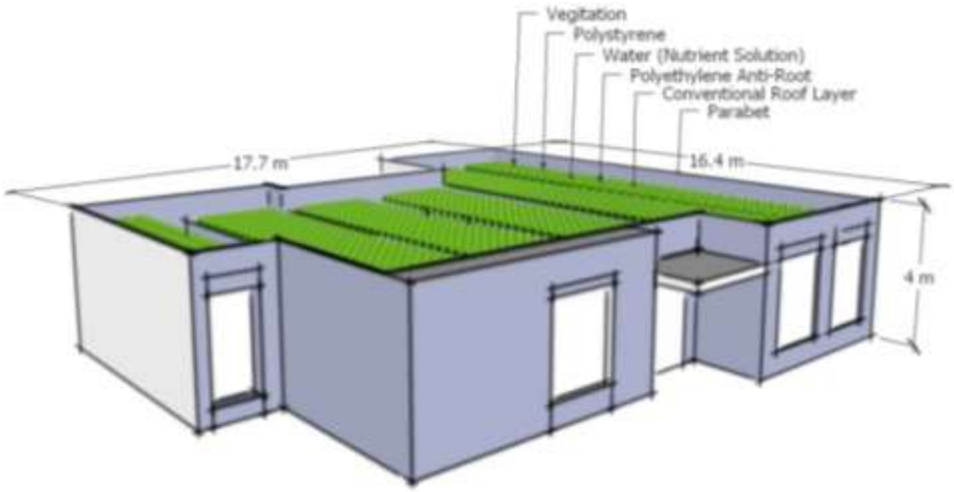


Figure 14.. Sketch illustrating building with hydroponic roof using Batavia lettuce plants

3.3. Materials

Conventional roof layers were used then a several brick walls with height of 0.3 m were added in a rectangular shape with different width ranging from 1.80 meter up to 2.4-meter, length and distances gaps are according to the building roof accessibility to allow maintenance. after words anti-roof waterproof membrane was installed followed by 0.15-meter nutrient solution and finally floating polyurethane Styrofoam, as illustrated in figure (15).

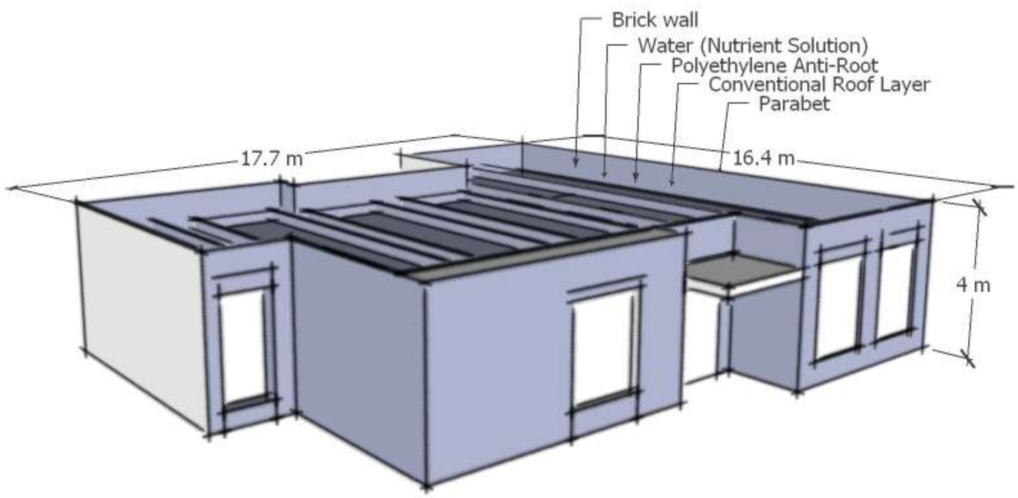


Figure 15. Sketch illustrating primer installation of hydroponic roof

Table 1, Comparison between Layers of Conventional Roof and Hydroponic Roof Generated by simulation program Ecotect from Autodesk 2011 [20] [21]

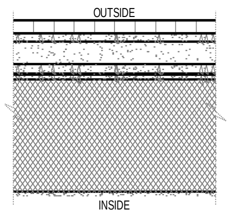
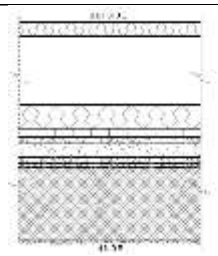
<table>
<tr><th>Roof Type</th><th>Section</th><th>Layers</th></tr>
<tr><td>Conventional Roof</td><td>

Figure 16, Roof Layers Generated by simulation program Ecotect from Autodesk 2011</td><td>
<table>
<tr><th></th><th>Layer Name</th><th>Width</th><th>Density</th><th>Sp.Heat</th><th>Conduct</th></tr>
<tr><td>1</td><td>Tiles</td><td>0.03</td><td>2760</td><td>836.8</td><td>0.562</td></tr>
<tr><td>2</td><td>Cement Mortar</td><td>0.02</td><td>1650</td><td>920</td><td>0.72</td></tr>
<tr><td>3</td><td>Sand</td><td>0.05</td><td>2240</td><td>840</td><td>1.74</td></tr>
<tr><td>4</td><td>Cement Mortar</td><td>0.02</td><td>1650</td><td>920</td><td>0.72</td></tr>
<tr><td>5</td><td>Bitumen</td><td>0.003</td><td>1700</td><td>1000</td><td>0.17</td></tr>
<tr><td>6</td><td>Reinforced Concrete</td><td>0.25</td><td>2500</td><td>656.9</td><td>1.17</td></tr>
<tr><td>7</td><td>Plaster</td><td>0.01</td><td>1570</td><td>840</td><td>0.53</td></tr>
</table></td></tr>
<tr><td>Hydroponic Green Roof</td><td>

,17 Figure Hydroponic Roof layers Generated by simulation program Ecotect from Autodesk 2011</td><td>
<table>
<tr><th></th><th>Layer Name</th><th>Width</th><th>Density</th><th>Sp.Heat</th><th>Conduct</th></tr>
<tr><td>1</td><td>Polystyrene Prefoamed</td><td>0.05</td><td>40</td><td>1130</td><td>0.042</td></tr>
<tr><td>2</td><td>Water</td><td>0.15</td><td>1000</td><td>4186</td><td>0.6</td></tr>
<tr><td>3</td><td>Bitumen</td><td>0.03</td><td>1700</td><td>1000</td><td>0.17</td></tr>
<tr><td>4</td><td>Tiles</td><td>0.03</td><td>2760</td><td>836.8</td><td>0.562</td></tr>
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<tr><td>10</td><td>Plaster</td><td>0.01</td><td>1570</td><td>840</td><td>0.53</td></tr>
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3.4 Limitation

In this section of the study, "Autodesk Ecotect Analysis 2011" is used for simulation. All elements, excluding the roof, are given fixed thermal properties in these simulations. The building was simulated during the summer, winter, and the entire year. This simulation took place in Alexandria, Egypt in two steps firstly to mimic the shading effect of vegetation hydroponic green roof as from the previous research papers and literature review the shading have a great effect in blocking the direct sun light and radiation thus, impacts the cooling process , the method used was similar to the one used in different papers to draw and simulate the buildings with shading devices were the vegetation is placed and voids where there is no vegetation. Finally calculating the energy consumption of HVAC system for heating and cooling during summer, winter and whole year for the conventional roof and for Hydroponic roof and compare the results to see which has less needs in terms of energy consumption [21] [22].

4. Discussion and Results

4.1. Effect of Solar Radiation and Heat Transfer

The primary goal of this research is to investigate the intensity of total solar radiation affecting the building's conventional external roof surfaces before it enters the building’s internal space, affect it, and compare it with intensity of total solar radiation with the presence of hydroponic green roof in Alexandria, Egypt. In this section of the study, "Autodesk Ecotect Analysis 2011" is used to simulate data for accumulative incident solar radiation on a horizontal surface on a seasonal and yearly period which, is usually expressed as an average value in Wh/m2.

After words calculating the difference in total solar radiation of conventional roof and hydroponic roof in the different periods which are summer, winter, and entire year in Alexandria, Egypt, finally finding the percentage of the total incident solar radiation reduction in the three periods by applying the formulas:

1. Difference Of Total Solar Radiation Between Conventional Roof and Hydroponic Roof (Wh/m^2)

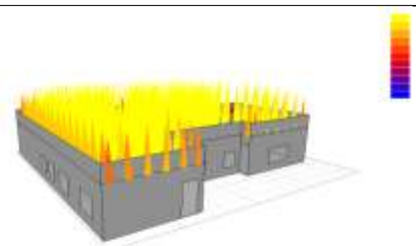
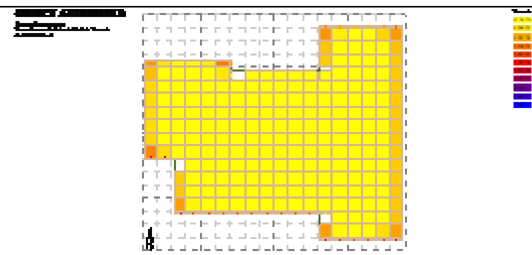
= Total Solar Radiation of Conventional Roof (Wh/m^2) _ Total Solar Radiation Hydroponic Roof (Wh/m^2)

2. Total Reduction of Solar Radiation % = (Difference of Total Solar Radiation Between Conventional Roof and Hydroponic Roof (Wh/m^2)/ Total Solar Radiation of Conventional Roof (Wh/m^2) *100

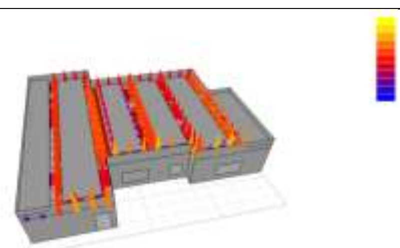
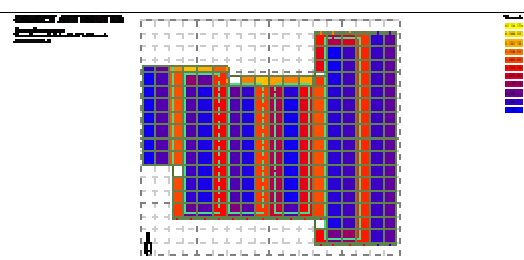
4.1.1. Summer Analysis of the building Alexandria, Egypt

From the below figures (16),(17),(18) and (19) which is Generated by simulation program Ecotect from Autodesk 2011 it is observed that there is a reduction in the total incident solar radiation of summer in conventional roof from 118,841,472 Wh/m^2 to reach 37,467,124 Wh/m^2 after applying the hydroponic green roof with total reduction of 81,374,348 Wh/m^2 to have total solar radiation reduction of approximately 68 % of the total solar radiation affecting the conventional roof.

4.1.1.1. Conventional Roof Model Summer Analysis of the building in Alexandria, Egypt

 *Figure 18 : 3D - Summer Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*	 *Figure 19 : Plan View - of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*
Total Solar Radiation in Summer	118,841,472 Wh/m^2

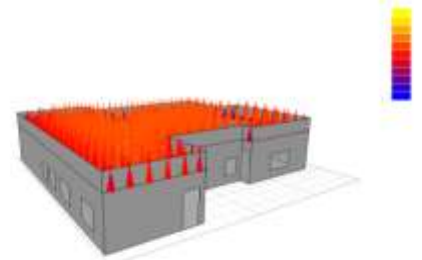
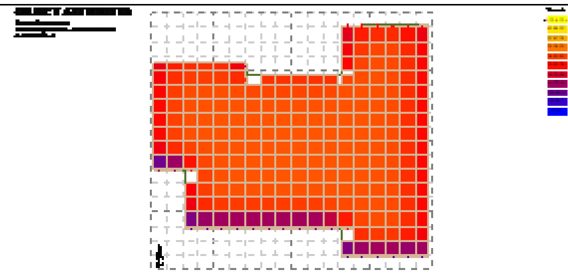
4.1.1.2. Hydroponic Roof Model Summer Analysis of the building in Alexandria, Egypt

 *Figure 20 : 3D - Summer Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*	 *Figure 21 : Plan View - of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*
Total Solar Radiation in Summer	37,467,124 Wh/m^2

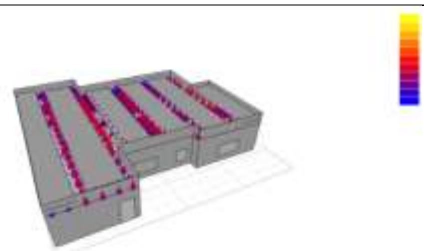
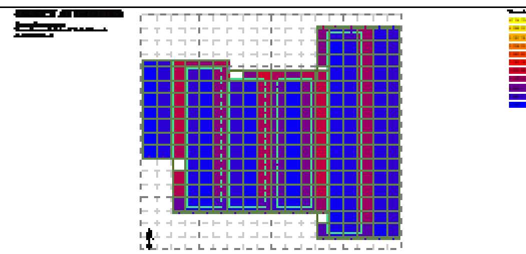
4.1.2. Winter Analysis of the building in Alexandria, Egypt

It is observed that there was a reduction in the total incident solar radiation during winter in conventional roof from 64,291,596 Wh/m² to reach 18,743,316 Wh/m² after applying the hydroponic green roof with total reduction of 45,548,280 Wh/m² which is approximately 71 % of the total solar radiation affecting the conventional roof, see figures (20),(21),(22) and (23) which is generated by simulation program Ecotect from Autodesk 2011.

4.1.2.1 Conventional Roof Model Winter Analysis of the building in Alexandria, Egypt

 *Figure 22 : 3D - Winter Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*	 *Figure 23 : Plan View - Winter Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*
Total Solar Radiation in Winter	64,291,596 Wh/m²

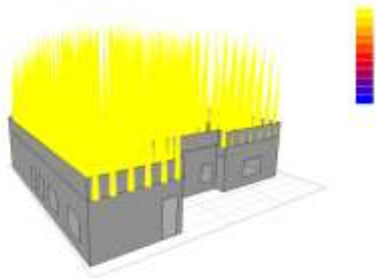
4.1.2.2. Hydroponic Roof Model Winter Analysis of the building in Alexandria, Egypt

 *Figure 24 : 3D - Winter Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*	 *Figure 25 : Plan View - Winter Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*
Total Solar Radiation in Winter	18,743,316 Wh/m²

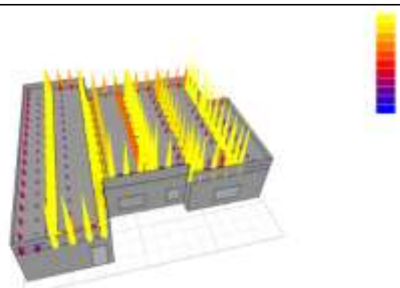
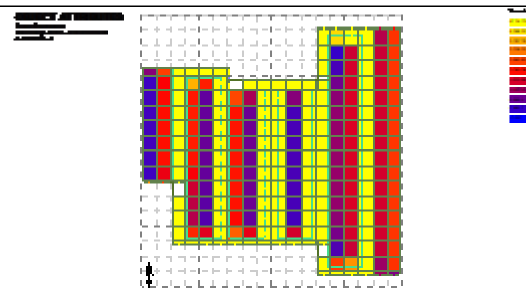
4.1.3. Entire year Analysis of the building in Alexandria, Egypt

From the below figures (24),(25),(26) and (27) which is generated by simulation program Ecotect from Autodesk 2011, it is observed that there was a reduction in the total incident solar radiation of entire year in conventional roof from 374,941,600 Wh/m² to reach 114,878,376 Wh/m² after applying the hydroponic green roof with total reduction of 260,063,233 Wh/m² which is approximately 69 % of the total solar radiation affecting the conventional roof.

4.1.3.1. Conventional Roof Model Entire Year Analysis of the building in Alexandria, Egypt

 *Figure 26 : 3D – Entire year Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*	 *Figure 27 : Plan View – Entire year Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*
Total Solar Radiation Entire Year	374,941,600 Wh/m²

4.1.3.2. Hydroponic Roof Model Entire Year Analysis of the building in Alexandria, Egypt

 *Figure 28 : 3D – Entire year Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*	 *Figure 29 : Plan View – Entire year Calculation of Total Incident Solar Radiation Generated by simulation program Ecotect from Autodesk 2011 [20]*
Total Solar Radiation Entire Year	114,878,376Wh/m²

4.1.4 Comparison between Total Solar Radiation of Conventional Roof and Total Solar Radiation of Hydroponic roof of the building in Alexandria, Egypt

Hydroponic system was added with a total floor area of ≈155m² from total floor area of the building ≈220m² which is ≈70 %. As shown in figure (28) it causes a reduction in total solar radiation in summer of ≈68%, winter ≈71% and through the entire year ≈69%.

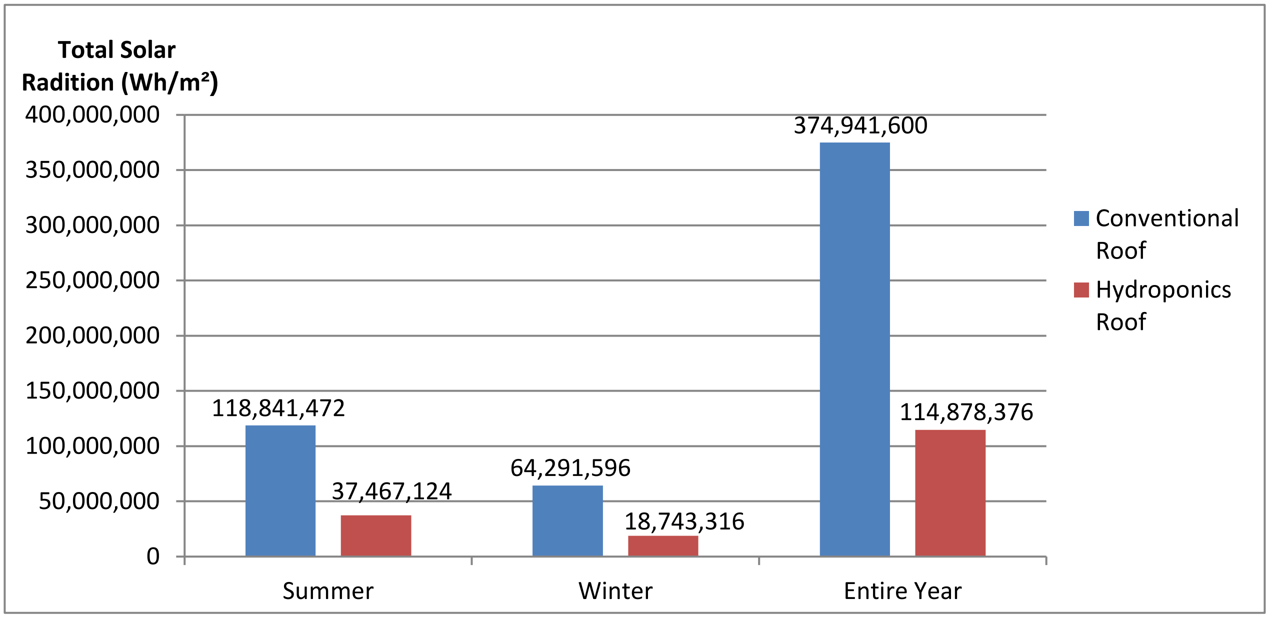


Figure 30. Graph of Comparison between Total solar Radiation of Conventional Roof and Hydroponic roof

4.2. Energy consumption of the building in Alexandria, Egypt

To understand the effect of hydroponic green roofs on the building HVAC energy consumption (heating loads, and cooling loads) which, will achieve a thermal comfort inside the building of an average temperature between 20ºC to 25ºC, an analysis was performed to compute and compare the conventional roof and hydroponic green roof in terms of HVAC energy consumption (heating loads, and cooling loads). All elements, excluding the roof, are given fixed thermal properties in these simulations. In this section of the study, "Autodesk Ecotect Analysis 2011" is used in the simulation process.

Table 2, Comparison between Energy consumption through the year of Conventional Roof and Hydroponic Roof of the building in Alexandria, Egypt generated by simulation program Ecotect from Autodesk 2011

Conventional Roof	Hydroponic Roof
MONTHLY HEATING/COOLING LOADS Zone: Building Operation: Weekdays 00-24, Weekends 00-24. Thermostat Settings: 20.0 - 25.0 C Max Heating: 9972 W at 05:00 on 26th December Max Cooling: 14046 W at 16:00 on 20th May	MONTHLY HEATING/COOLING LOADS Zone: Building Operation: Weekdays 00-24, Weekends 00-24. Thermostat Settings: 20.0 - 25.0 C Max Heating: 9963 W at 05:00 on 26th December Max Cooling: 13735 W at 16:00 on 20th May

Month	Heating (WH)	Cooling (WH)	Total (WH)	Month	Heating (WH)	Cooling (WH)	Total (WH)
Jan	1,587,750	0	1,587,750	Jan	1,475,296	0	1,475,296
Feb	1,853,898	0	1,853,898	Feb	1,763,909	0	1,763,909
March	1,327,655	0	1,327,655	March	1,245,626	0	1,245,626
April	426,352	187,547	613,899	April	335,026	171,933	506,960
May	47,643	937,576	985,218	May	31,076	800,807	831,884
June	0	2,083,107	2,083,107	June	0	1,756,144	1,756,144
July	0	2,619,237	2,619,237	July	0	2,237,115	2,237,115
August	0	3,457,970	3,457,970	August	0	3,045,266	3,045,266
September	0	2,313,618	2,313,618	September	0	1,992,097	1,992,097
October	23,997	860,007	884,004	October	0	726,028	726,028
November	495,962	0	495,962	November	418,329	0	418,329
December	1,285,847	0	1,285,847	December	1,182,689	0	1,182,689
Total	7,049,103	12,459,063	19,508,166	Total	6,451,952	10,729,391	17,181,344

4.2.1. Difference between Energy Consumption through the year of conventional roof and Hydroponic Roof of the building in Alexandria, Egypt generated by simulation program Ecotect from Autodesk 2011

- Heating:
  Total Energy Conventional Heating -Total Energy Hydroponic Heating= 7,049,103-6,451,952 = 597,151Wh
- Cooling:
  Total Energy Conventional Cooling -Total Energy Hydroponic Heating 12,459,063-10,729,391= 1,729,672 Wh
- Total:
  Total Energy Conventional -Total Energy Hydroponic
  19,508,166-17,181,344= 2,326,822 Wh

4.2.1.1. Reduction % in Energy Consumption through the year

- Reduction % of heating :
  $\left(\frac{\text{Total Energy Conventional Heating} - \text{Total Energy Hydroponic Heating}}{\text{Total Conventional Heating}}\right) * 100 = \left(\frac{7049103 - 6451952}{7049103}\right) * 100 =$ 8.47%
- Reduction % of cooling :
  $\left(\frac{\text{Total Energy Conventional Cooling} - \text{Total Energy Hydroponic Cooling}}{\text{Total Conventional Cooling}}\right) * 100 = \left(\frac{12{,}459{,}063 - 10{,}729{,}391}{12{,}459{,}063}\right) 100 =$ 13.88%

- Reduction % of Total : $\left(\frac{\text{Total Energy Conventional Total} - \text{Total Energy Hydroponic Total}}{\text{Total Conventional Total}}\right) * 100 = \left(\frac{19{,}508{,}166 - 17{,}181{,}344}{19{,}508{,}166}\right) * 100 =$ 11.93%

5. Conclusion

In this study, an environmental assessment of the influence of a hydroponic green roof on the thermal performance of a building in hot and humid climate was conducted (Alexandria). This research paper has discussed in detail the background, benefits, and thermal benefits of constructing green roofs rather than conventional roofing system which is, currently, present in the Egyptian residential buildings. The concerns about the decreased lifespan of the present buildings and their aesthetic appeal have predictably raised the need for a change into a more environmentally friendly system as opposed to the present one.

Despite the overwhelming dependence of green roofing systems on meteorological and climate changes, the construction of this system would improve air quality and even decrease the urban heat island effect in an urban point of view. Although the overhead costs would increase to from 1500 to 2500 Egyptian pound per square meter, the benefits of going green outweigh the risks of constructing it as this new system would enhance the well fare, boost job opportunities, and improve micro and macro-climate of the surrounding area. Furthermore, the green roofs have shown significant thermal energy benefits. Nevertheless, the average building has a maximum tolerance life load of 200 kg/m^2, thus hindering the construction of the regular green roofing that requires approximately 400 kg/m^2 for 10cm in depth soil thickness [4] and dooming it as inapplicable. Therefore, a hydroponic green roofing system, with a 100 kg/m^2 to 150 kg/m^2, would fit as the perfect alternative to it. The results which of this research was conducted by simulation program Ecotect from Autodesk 2011 proved that the use of hydroponic roof would reduce the total solar radiations up to 68% in summer and 71% in winter with a total of 69% reduction throughout the year. The HVAC energy consumption would be reduced by 8.74% with cooling energy consumption plummeting by more than 13%, leading to a total reduction of 11.83%.

The use of hydroponic roof system would eventually give rise to the possibility of building a sustainable green leafy agriculture that is 90% less reliant on water irrigation, thus leaving agricultural land to fruity crop. Despite the water shortage in Egypt, this technique could help the Egyptian food security sector. Moreover, it could supply steady income for entrepreneurs and lessen the percentage rates of unemployment.

The alternate use of hydroponic green roofs instead of conventional roofs helps in improving the thermal behavior of a building envelope, furthermore, if it’s adopted on an urban scale, it will decrease the urban heat island effect leading to many advantages to micro and macro climate.

6. Recommendations

The government should encourage the implantation of hydroponic green roofs as mentioned in the earlier chapters as it has a significant impact on the climate and society which, solves the problems in many economic sectors such as food security, unemployment, water shortage and agriculture. More research should investigate the direct and indirect effect of implanting hydroponic green roofs to obtain a deeper understanding and insight.

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تأثير السقف المزروع بالزراعة المائية على الأداء الحراري للمباني السكنية في مصر

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الملخص

الحاجة الدولية تجاه المباني الصديقة للبيئة في ازدياد دائم حيث انها اقل استهلاكا للطاقة بالإضافة لتقليل اهدار الماء في العديد من الدول، مما دفعها لتبني فكره بناء الاسطح الخضراء. هذه الدراسة مخصصه للتحقيق في كيفية تحسين كفاءه الاداء الحراري للمباني السكنية القائمة بالفعل في مصر عن طريق ايجاد بديل للأسطح الخضراء التقليدية، حيث ان المباني المصرية القائمة بالفعل لا تستطيع تحمل وزن الاسطح الخضراء التقليدية لأنها تحتاج تقريبا الي ٤٠٠ كجم / م ٢، لعمق ١٠ سم للتربة في حين ان المباني المصرية مصممه لتحمل ٢٠٠ كجم / م ٢ الحل المقترح في هذه الدراسة سيعالج المشكلة الأساسية لدي الحكومة المصرية في قطاع استهلاك الطاقة وترشيد استهلاك المياه. الهدف الأساسي لهذا البحث هو حساب شده الاشعاع الشمسي الكلي المؤثر على سطح المبني الخارجي قبل تأثيره على الحيز الداخلي للمبني. في هذه الدراسة نقوم بحساب تأثير الاشعاع الشمسي على المبني قبل وبعد وجود أسطح الزراعة المائية. اكدت الدراسة ان استخدام أسطح الزراعة المائية سمحت بزراعه ورقيات اقل اعتمادا على الري بالمياه بنسبه ٩٠٪، كما أن الاشعاع الكلي للشمس قل بنسبه ٦٩٪ خلال العام واستهلاك الطاقة قل بنسبه ١١.٩٣٪ تقريبا.

الكلمات الدالة: السقف الأخضر، السقف المائي، الاستدامة، الأداء الحراري

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