International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 5 Issue 2, February 2018

ISSN: 2394-4404

The Effect Of Green Roof On Energy Used For Cooling And Heating Office Buildings In A Warm And Dry Climate

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Abstract: The emergence of computers and other electrical appliances in office buildings has raised the indoor temperature of these buildings and, despite the extensive glass views, increase the internal temperature. The question is how one can maintain the comfort of the interior, while having a wide glass view for visual communication with outside, without increasing the amount of cooling energy used.

The purpose of this paper was to specify the effect of green roof on the cooling and heating load of a building in a warm and dry climate.

The method was causal research and simulation. The tool used was Design Builder thermal simulator software. The building with and without green roof was modeled and analyzed to obtain the effect of green roof on the energy used for cooling and heating.

The use of a green roof in the building will save up to 2.o3 kilowatts per square meter for building cooling. However, the use of green roofing in the building increased the energy consumption for heating and this is 2.78 per square meter. This decrease and increase, respectively, in the cooling and heating load were due to the difference in receiving rays of sunrays in a building with and without a green roof.

Keywords: green roof, energy consumption, cooling and heating, warm and dry

I. INTRODUCTION

The use of sustainability concepts and sustainable development in architecture is the beginning of a topic called sustainable architecture. Sustainable architecture is a native feature. Sustainability, in spite of its all-encompassing slogans, targets the issue of preserving the land, advocating local approaches and thinking about global slogans to reach applicable practices and protect the diversity that exists in nature [1]. The definition given at the Rio Conference for sustainable development is "A development meeting the current human needs without jeopardizing the needs of future generations, while paying attention to the environment and future generations [2].

Inspiration by nature can be used in many building features. For instance, the use of natural herbs, natural light, natural ventilation, and temperature characteristics of the earth and other forces of nature can all be seen as patterns of nature's use. In addition, the use of natural potential is evident in the planning at urban scale. One of these potentials is the green roof [3].

Green roofs can reduce energy consumption in the building. Thus, this roof, besides protecting the building components is effective in energy consumption in the building, making the cities more beautiful. Seeking and investing in the technology of green roofs and walls is the most important method enabling the cities to develop with certainty the protection of the environment and the survival of human life. In this regard, in Iran, given the presence of thermal islands and the increase of temperature in urban centers, due to the growth of non-standard and non-homogeneous urban texture, fossil fuels consumption increases as well. It seems that it is the high time to study and apply the use of green roof and green wall as an effective way to optimize energy consumption and more sustainable urban modernization in building regulations [4]. In the last few years, great actions are taken in the country by the Fuel Economy Optimization Organization (affiliated to the Ministry of Oil) to save energy in all sectors of the economy, especially in the construction and operation of buildings. According to the 19th National Building Regulations on Energy Saving and the Advantages of Green Roofs on Energy Saving and, because of Sustainable Urban Development, greening the roofs can also act in line with national construction policies. The green roof, also known as vegetable roofing, is a light weight engineering system that allows plant to grow in the roof while protecting the roof. In the other definition, a green roof is a roof covered with or intact with the growing medium [5].

The idea of creating a garden on the roof and planting on it was started by the Iranians 2500 years ago and on the roof of the ziggurat. In addition, green roofs were built by the people of Babylon 600 years BC. The hanging gardens of Babylon were not really gardens suspended in the air, but were green spaces on the roofs and moonlit of the buildings [6]. The development of green spaces on roofs has improved fast in recent years, especially in Europe and the United States. The reason behind this is the tendency to reduce energy consumption in the building. In Germany, the United States, Singapore, Japan and other countries, governments have provided services to encourage citizens to use green roofs [7]. Germany is the first country to use today's modern green roof. The German Landscape Research, Development and Construction Society (FLL) has expanded the use of green roofing since 1970. With the constant research and development, there is more than one million square meters of green roof space in Germany. The guideline of Green Roofing Board of the German Landscape Research and Development Office is also accepted and used in many countries of the world [8]. The United States also uses the technical expertise of Europeans because of the lack of technical information on green roofs [9]. In this study, data from FLL were used, too [10]. The main reason to focus on green roof, besides the architectural aesthetics, is the answer to factors such as the thermal insulation, moisture and natural sound of the building, the use of the dead space of the roof to create a pleasant atmosphere, create eye-catching faces, combining artifacts with nature, helping to reduce Atmospheric contamination, increasing air oxygen and increasing the stability and proper management of flood rains and rainwater, and so on [11]. Green roof is a roof covered either with vegetation and soil, or with a growth medium. The term Green Roof is used for roofs that take into account green architectural concepts. Green roofs are the roofs that plants grow on its surface. Vegetation diversity of such a structure can be from the roof of the artificial grass roof to the bamboo garden covered with plants used in landscape design.

II. THE NEED FOR A GREEN ROOF

The increasing pollution of mega cities and the city's major needs for ecological projects are evident. Considering the high cost of land and the lack of green space in the city, besides the benefits of green roofing in saving energy, the environmental benefits of green roofs should also be considered. Under such circumstances, by encouraging citizens to implement a green roof plan, at least about one fifth of the city's green area could be reduced and air pollution significantly reduced [12]. The benefits of green roofs can be used and can be hopeful for its sustainability to pursue and implement in the framework of sustainable macro development programs and in the Green Branch. For example, a neighborhood could be selected in Tehran metropolis and run the green system [13, 14].

III. METHODOLOGY

The method was based on causal and simulation studies. “The best and, at the same time, the most convincing way to create a causal relationship is an exact test in which the effect of latent variables is controlled. The meaning of the experiment is to change the active X and see its effect on Y” [15]. The test tool was a simulation by a thermal software in search of finding the effect of different conditions in terms of the inner and outer layers of the double-faced façade and the number of walls of these two layers. Measuring the variables is done by calculating the exact change in energy consumption.

Simulation in this study was done by using the Design Builder software, which is software for thermal analysis of buildings that measures the effect of environmental factors on the building. The capabilities of this software include calculating the total energy consumption of the building, calculating the cooling and heating load of buildings, illustrating solar radiation on windows and other surfaces, calculating daylight factors and showing the position of the sun and the direction of the sun compared to the model in each day and hour. This software can calculate the energy consumed in hours, days, months and years based on climatic information and help the design team take design decisions according to actual information. The validity of the Design Builder software has been proven in numerous previous studies. By referring to the main page of this software site, one can see that in the United Kingdom's decision-making bodies, the results of the simulations are fully valid and recognized by introducing the characteristics and climate data of different regions [16]. To state some examples of previous studies with Design Builder software, one can study the behavior of office buildings from in terms of energy consumption to achieve energy efficiency by evaluating the effect of different architectural indices like orientation, level of openings in different fronts, awnings, natural ventilation and air exchange rate through leakage on energy consumption of buildings, using energy modeling (with Design Builder software) [17].

Using the Design Builder simulation software, according to Figure 1, a building with a length and width of 3 meters and a height of 3.5 meters was simulated using green roof in a warm and dry climate and the behavior of the thermal behavior of the building was examined. Then a building with a similar feature to the previous building but without the green roof was also simulated.

Figure 1: The sample simulated in Designbuilder software

Finally, according to the extracted graphs of this software, we dealt with data analysis, and in the end, according to the data analysis, the thermal behavior of the building with and without green roof were determined.

CLIMATIC DATA OF THE SAMPLE

A review of the literature suggests that many studies are done on green roofs and their effect on energy efficiency. However, the different climates of each region could lead to different results. Therefore, the city weather information was extracted from the beginning of the year 1992 to the beginning of 2003 [18] and entered as Energy Plus file into Design Builder software, with the climatic information shown as in Figure 2.

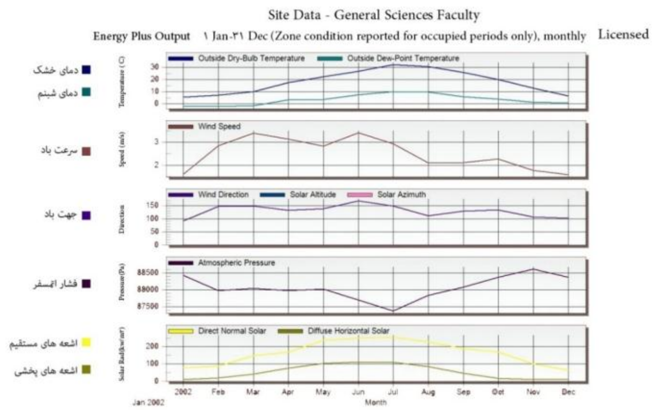

Figure 2: Climate information extracted from Designbuilder Software

Figure 2 shows the weather information of the city presented over a one year.

IV. THERMAL BEHAVIOR ANALYSIS OF BUILDING WITH GREEN ROOF

Green roof is a proper replacement for degraded urban spaces, improving the microclimate of the local climate, reducing heat recovery and adjusting the indoor thermal conditions [19]. Green roofs are made up of several layers to provide a surface for the growth, as well as drainage of excess water on the roof. As shown in Figure 3, these layers have the layer of the plant, the soil, the drainage, the shell of the water, and the membrane substrates. Depending on the depth of the soil, there are two categories in the green roof: extended green roofs and compressed green roofs [20]. Compressed green roofs have deeper layers that can have larger-sized plants that give more beauty to the building. The compact green roof has a lower depth layer, which reduces the cost of roofing. It also enters less weight to the building [19]. This study examined extended green roofs.

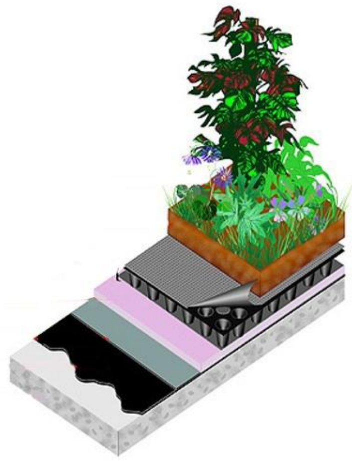

Figure 3: Green roof's Layers

According to Figure 4, simulated green roof in Design Builder has a total depth of 40 cm, of which 15 cm is related to the plant. The conductivity and heat radiation of each layer along with the heat transfer coefficient and the thermal resistance of the entire green roof structure are given in this figure [21].

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.372
R-Value (m2-K/W)	2.856
U-Value (W/m2-K)	**0.350**

Figure 4: Thermal properties of green roof

The leaf area index (the leaf area relative to ground level) is four in the green roof (Figure 5).

Green Roof	
☑ Green roof	
Height of plants (m)	0.1500
Leaf area index	4.0000
Leaf reflectivity	0.220
Leaf emissivity	0.950
Minimum stomatal resistance (s/m)	100.000
Max volumetric moisture content at saturation	0.500
Min residual volumetric moisture content	0.010
Initial volumetric moisture content	0.150

Figure 5: Characteristics of the Green roof

According to Figure 6, the outer wall is composed of 4 layers with a thickness of 292.5 mm, and the cross-section and thermal properties of the outer walls are shown. In addition, the conductivity and radiation radiations of heat and heat of each layer, along with the heat transfer coefficient and thermal resistance of the entire structure of the wall are shown in this figure [22].

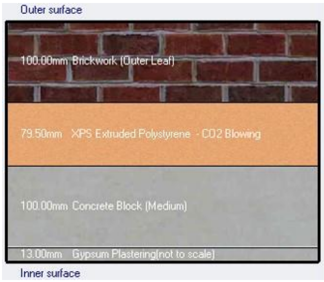

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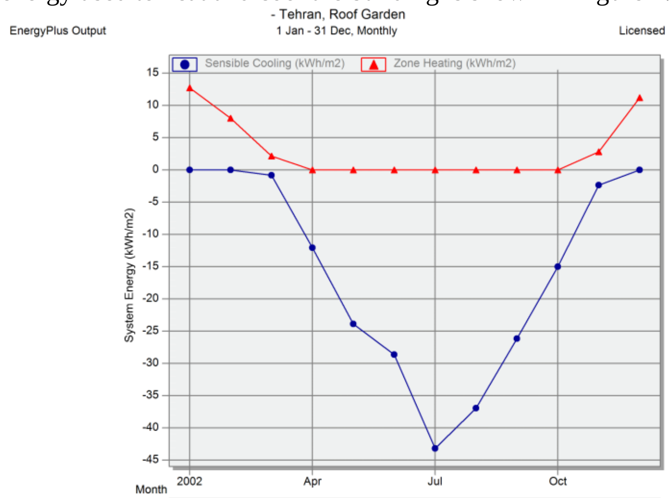
Figure 6: Thermal characteristics of outer wall

According to the information entered to the software, the energy used to heat and cool the building is shown in Figure 7.

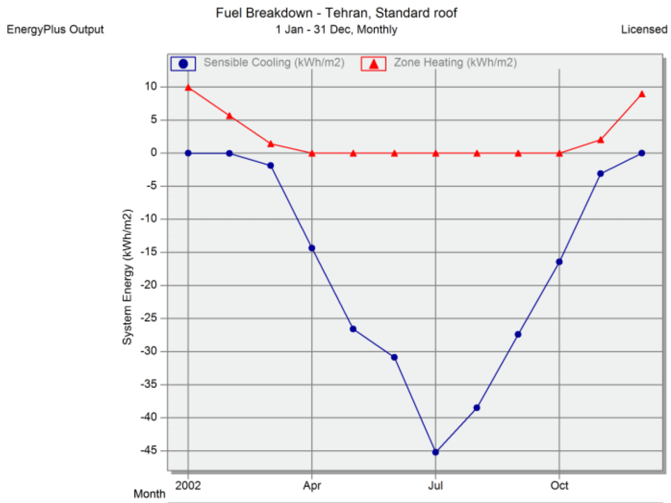


Sensible Cooling (kWh/m2)	0.00	-0.00	-0.80	-12.04	-23.87	-28.63	-43.17	-36.92	-26.15	-14.99	-2.36	0.00
Zone Heating (kWh/m2)	12.73	8.03	2.15	0.02	0.00	0.00	0.00	0.00	0.00	0.03	2.83	11.21

Figure 7: The amount of energy needed to warm and cool a building with green roof

According to Figure 2, the coldest and warmest months of the year are January and July, respectively. According to Figure 7, the cooling time in July is 43.17 and the heating load in January is 12.73 kWh per square meter.

Then, the building was simulated with the same dimensions and features as the previous building without the green roof. Figure 8 shows the amount of energy used to cool and warm the building without a green roof for every square meter.



Sensible Cooling (kWh/m2)	-0.00	-0.02	-1.88	-14.35	-26.58	-30.84	-45.20	-38.48	-27.40	-16.43	-3.10	0.00
Zone Heating (kWh/m2)	9.95	5.68	1.42	0.01	0.00	0.00	0.00	0.00	0.00	0.02	2.05	8.98

Figure 8: The amount of energy needed to warm and cool a building without green roof

According to Figure 8, the cooling load in July and the heating load in January are 45.20 and 9.95 kWh per square meter, respectively.

By comparing Figs. 7 and 8, using a green roof in the building, the 2.03 kWh per square meter is saved for building cooling, whereas the use of green roofing in the building has increased the energy consumption for heating, this is 2.78 per square meter. This decrease and increase, respectively, in the cooling and heating load are due to the number of rays in sunrays in a green roofed building without green roof. According to Figure 9, the green roof will lose heat in the summer, which will reduce the cooling load of the building. Loss of heat in the green roof during the cold season is higher than the standard roof (Figure 10), which increases the heating load of the building.

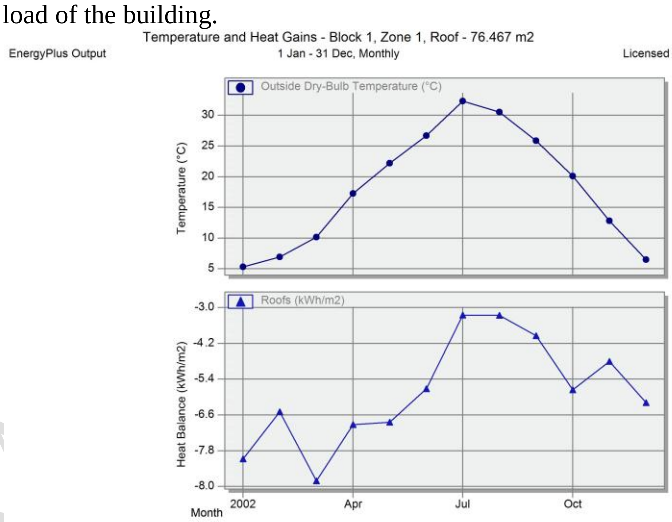
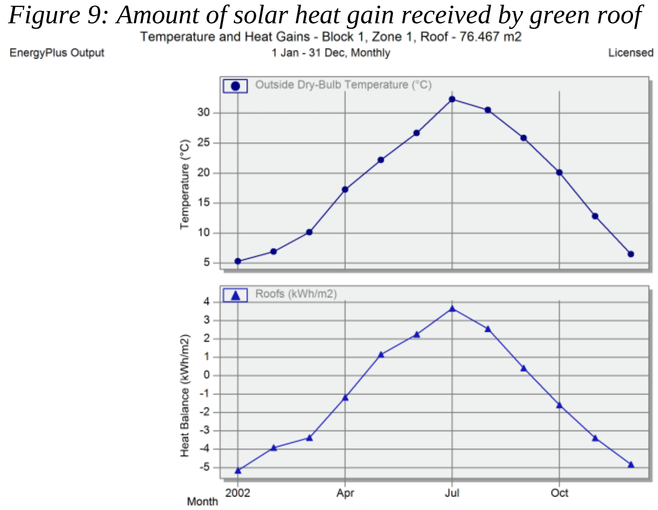


Figure 9: Amount of solar heat gain received by green roof



Outside Dry-Bulb Temperature (°C)	5.34	6.96	10.16	17.29	22.20	26.71	32.31	30.55	25.88	20.10	12.81	6.50
Roofs (kWh/m2)	-5.14	-3.92	-3.37	-1.18	1.16	2.26	3.66	2.56	0.42	-1.59	-3.38	-4.83

Figure 10: Amount of solar heat gain received by regular roof

V. CONCLUSION

In the simulation, data was analyzed by entering data and detailed details. The use of green roof has resulted in energy savings of up to 2.03 kWh/m^2 in the heating season. This is due to the loss of heat in the green roof. Therefore, even in July, the warmest month of the year, the green roof loses heat at 3.2-kilowatt hours per square meter. While a standard roof

 ISSN: 2394-4404

(without green roofs) is receiving the heat from the sun in the same season of the year, it is 3.66 kWh / m2. This will reduce the cooling load of the building with the green roof during the heating season. By comparing Figures 8 and 9, it is found that the heating load of a building with a green roof is more than a standard roof structure. Loss of heat in the green roof during the cold season is higher than the standard roof (without green roofs), which increases the heating load of the building.

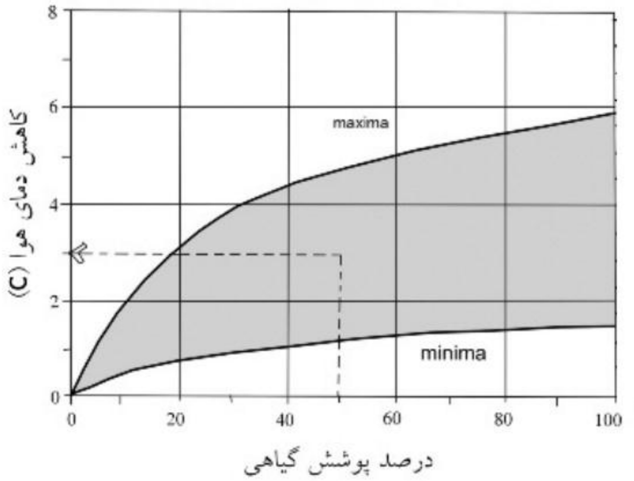


Figure 11: Cooling provided by plants evaporation

It should be noted that the use of green roof in buildings will increase the urban green area and, as shown in Figure 11, if we allocate 25% of the roof to the green roof and add this to the green spaces available. We can reduce city heat by 3 degrees. However, it is necessary to consider the reduction in energy by the green roofs is measured with economic considerations.

This study investigates the effect of green roofs on warm and dry climate, and other researchers can examine the effect of green roof on energy consumption in cold climate. It is also possible to compare the wide and compact green roofs regarding effects on energy consumption in the building as well.

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