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ASSESSMENT OF ECONOMIC WORTH OF GREEN ROOF: A CASE STUDY IN PUTRAJAYA

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Abstract

The current global temperature rise has affected local climate change issues and increased the energy usage for the building cooling process. Following this, the roof components have been identified to contribute the building heating effect due to exposure for more than 10 hours a day which at the same time secretes 70% of the sun's radiation. As an alternative, the green roof concept approach potentially reduces the effects of internal heat and operating costs of cooling the building while providing an investment return for the desired period. This study aims to measure the level of effectiveness of the building green roof concept on the building cooling rate and its profitability implications. Two objectives have been set. First, to compare the effects of concrete and green roof applications on energy consumption and operating costs for the cooling effects of air-conditioned buildings (active systems). Second, to evaluate the maintenance cost and profitability of applying the green-roofed building concept in terms of periodic return on investment. The findings of this study are seen to help the government and relevant agencies consider using the green roof concept in the physical construction of buildings in the future.

***Keywords**:* Green Roof, Energy Consumption, Operating Cost and Return on Investment

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INTRODUCTION

The impact of the local climate on the wishes of building owners or users has led to the need for a current mode of operation that can save energy for the cooling effect of the building (active system), savings and gains in operating and maintenance costs for an irregular period. This scenario makes building designers in Malaysia begin to tend toward the concept of green buildings where innovation and improvement begin to be adapted in their output. To evaluate the effectiveness of existing green buildings, this study will look at the specific performance of the main components of the building, namely the roof of the Herald Watt University building in Putrajaya and it can be seen in picture 1.

For the implementation of this study, two objectives have been set. First, to compare the effects of concrete and green roof applications on energy consumption and operating costs for the cooling effects of air-conditioned buildings (active systems). Second, to evaluate the maintenance cost and profitability of applying the green-roofed building concept in terms of periodic return on investment. The scope of this study will focus on the roof components of case buildings as the main subject by changing the specification parameters and conductivity values of its building materials. Basically, the study aims to justify the cost of construction, operation, maintenance and investment profitability in recommending the concept of green roofs for government buildings in the future.

Picture 1: Herald Watt University building in Putrajaya.
Source: https://www.educationmalaysia.in/university/heriot-watt-university-malaysia-hwum

GENERAL OVERVIEW ON GREEN ROOF CONCEPT

The increasing energy consumption on the operation of buildings due to the increase in the local outdoor climate is closely related to the impact of the urban heat island. Among the current solutions that are considered the best is applying the green roof concept to buildings, which is one of the main criteria of green building. The decision to plant a green landscape on the entire surface of the main roof has created a natural environment that protects the construction of the buildings it shelters. The basis of the effectiveness of this concept is entirely dependent on the landscape, where periodic care and maintenance must be carried out as best as possible

Malaysia's geographical location at latitude 3.12 ºN and longitude 101.55 ºE has placing it in the group of tropical climate countries, it is easy to experience thermal discomfort if the design strategy fails to reduce the increase in heat entering the building space (Zain et al. 2007). A study found 73% of the heat absorption rate of solar radiation is contributed by the facade of the building (U. S. DoE 2011), it is absorbed by the surface of the wall components and roof when exposed directly to the sun (Ralegaonkar & Gupta 2010). The effects of being exposed to solar radiation for more than 10 hours a day throughout the year will spread the heat of solar radiation into the interior space through the facade of the building in various directions (Ibrahim et al. 2014). R. Daghigh's study found that daytime temperatures can reach 24 ºC to 34 ºC and relative humidity between 70% to 90% can occur throughout the year (Daghigh 2015).

It is known that the effect of solar radiation on the roof surface will determine the atmosphere of the indoor environment of a building that affects the condition of its occupants ((Sadineni et al. 2011). Thus, the recommendation of strategies and accurate technical understanding must be practised to reduce the rate of solar absorption and at the same time, save the use of active energy for the internal thermal comfort of the building (Mirrahimi et al. 2016). The green roof concept approach is seen to be able to form the character and improve the current performance of the building as a method of integrating the building design with an intricate system of natural plant cultivation, either in a simple or complex way (Kamarulzaman et al. 2014). It can also create a more aesthetic eco -friendly environment to work in, increase productivity and guarantee a return on investment compared to traditional roofs (Rowe 2011).

Studies have found that the roof temperature measurement for a building without the green roof concept is around 42 ºC to 48 ºC while the green roof is around 28 ºC to 40 ºC (Niachou et al. 2001). If the roof and green walls are combined, it can lower the thermal transmittance to the interior space of the building up to 0.27 W/m2 K [13]. A study simulating the impact of the green roof concept in Malaysia found that it can reduce by 47% the temperature rise of the roof of a building (Kok et al. 2016), at the same time contributing to the energy saving of the building (Asmat et al. 2008).This also involves such as plant selection, rainwater harvesting system, pest control, accessibility, irrigation cleaning, waterproofing membrane maintenance, plants and growing medium (Zaid et al. 2022).

Construction details are also a success factor of this technology where the composition of green roof building materials must be well defined and the optimal material selected because its efficiency refers to the accessibility of the material as well as geographical location (Cascone 2019). To set the direction of the concept of green buildings that are still considered foreign, a statistical approach to the data set must be made first on rainfall intensity, substrate depth, surface coverage, climate type, vegetation types and season types on runoff retention performance (Zheng et al. 2021).

The performance and efficiency of green roofs vary according to design parameters and models developed in estimating Roof Thermal Transfer Value (RTTV) and U-values at the design stage again and adjusted according to current climatic conditions and local thermal performance evaluation index (He et al. 2021). Studies on green roofs in Malaysia have already begun as early as 1990, but this technology has not been fully accepted, and therefore, the government should set the percentage of its application in development in urban areas (Isa et al. 2020). Due to the dense development density in the city, it becomes a strategic factor in implementing green roofs because of its benefits of reducing the effects of greenhouse gas emissions, the effects of urban heat islands and air pollution (Zaid et al. 2022). Overall, the green roof concept is one of the specific approaches to a building to reduce the internal thermal effects and operation costs of cooling the building while providing an investment profit for the desired period.

RESEARCH METHODOLOGY

There are two methodological frameworks for this study, on-site measurements and building modelling simulation. For the on-site measurements, the acquisition of actual case-building data is the core information in making the basics and developing the feasibility of the study assumptions. A room under a green roof measured the heating effect of its surface and indoor air temperature. These reading records were measured comprehensively over three consecutive weeks (7 to 21 October 2021) to record data and to read patterns. Internal thermal performance is influenced by air temperature factors and is supported by wind velocity and relative humidity. For the study, the focus will be to pay special attention to the indoor air temperature that affects the cooling of the space and its operating costs.

Meanwhile, for building modelling simulation, the simulation results for this study are numerical, where the simulation engine is based on thermodynamic standard equations in the Apache module of Integrated Environmental Solution-Virtual Environment (IES-VE) software. 50 interior spaces were constructed and set with the actual building material specifications and air conditioning system service. Building location input, local climate information and building materials were adjusted at the beginning of the simulation process. Finally, the simulation results have generated energy values for cooling the entire building and estimated operating costs for a year.

RESULT AND ANALYSIS

a. Simulation effect of green roof on the study building

The priority of the study is to compare the effect of a green roof with a concrete roof on 50 rooms and space compartmentation (lecture room, office and all occupied spaces) by applying an air conditioning system starting from 6.30 to 18.30 on 29 March 2022 (the highest air temperature reading in the previous simulation result). The building's central air conditioning system was activated during the daytime working session with a fixed value of 26.0 ° C.

b. Mean radiant temperature (MRT) simulation results

Mean Radiant Temperature (MRT) is the effect of temperature refraction from the surface around the room's perimeter with its conductivity value and u-value. From the simulation result, the MRT readings for green-roofed and concrete-roofed buildings have almost the same pattern for promenade level, ground level and level 1. However, it differs on level 2, where this level interacts continuously with the roofing material. At the same time, a reading difference of around 1.84% between green-roofed buildings and concrete-roofed buildings has been successfully recorded. The impact of the MRT temperature difference for these two roof categories has shown that the performance of green-roofed buildings can curb the effect of MRT temperature, especially at level 2 (highest level) and lower the MRT temperature for promenade level by 0.18%, ground level by 0.11% and level 1 by 0.57%. Figure 1 explains the statement that has been revealed.

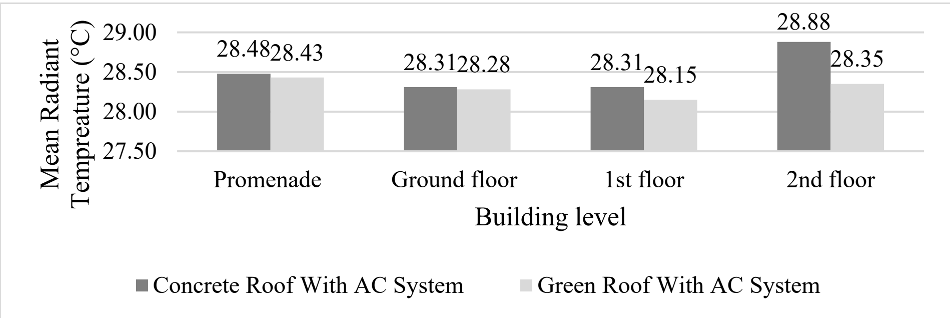

Figure 1: Comparison of simulation results for average MRT temperature for 4 levels of study building on 29 March 2022 from 6.30 to 18.30.
Source: Authors (2022).

c. Conduction gain simulation results from the roof component

Referring to figure 2, the pattern of average energy rate readings resulting from this green and concrete roof heating effect has shown a decreasing similarity starting from 6.30 am to 10.30 am, then it started to show a very significant energy reading difference up to 18.30 am. This scenario is due to the solar impact reception factor that begins to increase and accumulate on the roof components and at the same time, secreted into the interior. In this situation, the green roof has shown its positive performance at the critical time, starting from 11.30 am to 18.30 (8 hours).

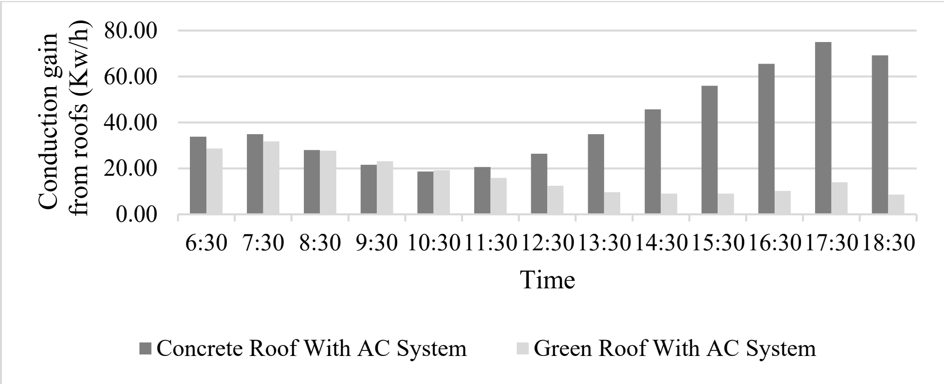

Figure 2: Comparison of the conduction gain at level 2 roof between green and concrete roof on 29 March 2022 from 6.30 to 18.30.
Source: Authors (2022).

For 13 hours a day with the activation of the air conditioning system, the observation found a significant difference in the conduction gain (roof) reading for the concrete-roofed floor 2 space with the green-roofed space at 310.88 Kw/h in total. Here, an energy-saving rate of 41.36% (530.14 Kw/h / 219.26 Kw/h) was created after optimizing the function of the green roof on the study building. This situation can be seen clearly in table 1 as shown.

For the estimated cost of cooling the entire space on level 2, this study referred to TNB Malaysia's medium commercial tariff (from excel – TNB rate) for one year. A building with a concrete roof will cost RM 4,644,026.40 (10,602.80 Kw/h x RM 36.50 x 12 months) while the green roof is RM 1,920,717.60 (4,385.20 Kw/h x RM 36.50 x 12 months). Overall, cost savings per year with a value of RM 2,723,308.80 or 41.36%, can be achieved if the green roof concept is applied to the study building.

Table 1: Comparison of conduction gain readings for the space on level 2 of the study building with green roof and concrete roof.

Room condition on the 2nd floor	**The conduction gains from roof component for level 2**						
	Minimum Reading (29 Mac 2022)		**Maximum Reading (29 Mac 2022)**		**The average of energy formed per day / 13 hours (29 Mac 2022)**	**The average of energy formed per month / 20 working days**	**The average of energy formed per year / 12 months**
	(Kw/h)	**Time**	**(Kw/h)**	**Time**	**(Kw/h)**	**(Kw/h)**	**(Kw/h)**
Concrete roof with AC system	18.67	10.30	74.99	17.30	530.14	10,602.80	127,233.60
Green roof with AC system	8.58	18.30	31.76	7.30	219.26	4,385.20	52,622.40

Source: Authors (2022).

d. Simulation results of conduction gain results for the entire building

To comprehensively compare the green roof effect's performance with concrete, the results of conduction gain simulation data will be divided by level. This aims to facilitate comparisons and see the relationship. Referring to figure 3, the reading patterns for the two roofs at promenade level, ground level and level 1 seem to be the same but very different for level 2. An extensive reading gap of 310.88 Kw/h is formed at level 2 and this indirectly proves the effectiveness of green roofs in reducing the employment rate of space cooling.

It is very clear from the simulation results generated that a high energy rate exists at level 2 or more specifically, under the main roof that shelters the space. Previous studies have proven that roofing in tropical climates will contribute to 70% of the thermal effect and it will increase the high energy rate for the cooling effect (Al-Obaidi et al. 2014). In this study, the reading of the concrete roofed floor 2 space has shown an increase of 50.33% (reading 2 level / total reading for all level, sheet kW/h) of the total building energy generated, while the green-roofed building level 2 is around 30.14% (reading 2 level / total reading for all level, sheet kW/h).

The estimated cost breakdown for cooling a green-roofed or concrete building either by building level or the entire building can be seen clearly in table 2. Overall, a saving of RM 2,855,059.20 for one year will occur if green-roofed buildings are utilized as much as possible compared to concrete roofed buildings only.

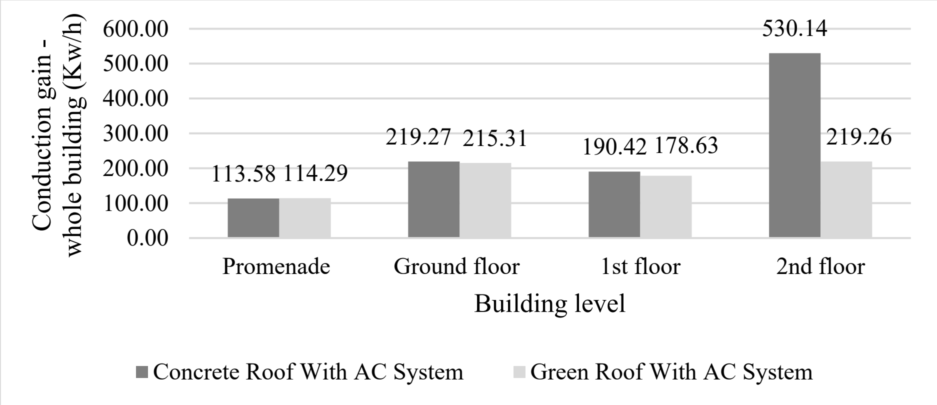

Figure 3: Comparison of the conduction gain for the whole building between green and concrete roof on 29 March 2022 from 6.30 to 18.30.
Source: Authors (2022).

Table 2: Comparison of conduction gain readings for the whole building between green roof and concrete roof.

Building condition	**Building level**	**The average of energy formed / Kilowatt / hour (Kw/h)**			**Cooling cost by building level (RM)**	**Total cooling cost for whole building (RM)**
		Per day / 13 hours	**Per month / 20 working days**	**Per year / 12 months**		
Concrete roof with AC system	Promenade	113.58	2,271.60	27,259.20	994,960.80	9,227,871.60
	Ground	219.27	4,385.40	52,624.80	1,920,805.20	
	1st floor	190.42	3,808.40	45,700.80	1,668,079.20	
	2nd floor	530.14	10,602.80	127,233.60	4,644,026.40	
Green roof with AC system	Promenade	114.29	2,285.80	27,429.60	1,001,180.40	6,372,812.40
	Ground	215.31	4,306.20	51,674.40	1,886,115.60	
	1st floor	178.63	3,572.60	42,871.20	1,564,798.80	
	2nd floor	219.26	4,385.20	52,622.40	1,920,717.60	

Source: Authors (2022).

d. Maintenance of green roofed building

The effectiveness of the green roof concept can only be achieved if the grassy area coverage surface can be kept consistently fresh at all times. Therefore, periodic maintenance and treatment must be made and recommended to be carried out by a competent contractor. The total green roof area for this study building is 10,126.15 m², it starts from ground level to shades the space on level 2. The basic cost estimate refers to the maintenance price list of the Public Work Department (PWD) and the National Landscape Department found that the maximum cost of the entire green roof for one year will amount RM 2,284,432.88. The details of work and prices can be referred to table 3.0.

Table 3: Details of work and maximum estimated price for green roof maintenance for a one-year period.

Scope	Unit	Coverage	Period	Work price (RM)	Cost (RM)
Grass watering	m²	10,126.15	2 times / month	0.80/ m²	1,944,194.88
Grass fertilization	m²	10,126.15	4 times / year	5.90 / m²	238,977.00
Replacement and replanting of sized grasses	m²	5,063.08 (50% from 10,126.15 m²)	1 time / year	20.00 / m²	101,261.60
Estimated total cost					2,284,432.88

Source: Authors (2022).

e. The energy saving costs generated from the green roof effect

Based on the financial aspect, a profit to the owner or user of the building of RM 570,626.32 per year can be obtained if the operating cost of the concrete roofed building is deducted from the operating cost of the green-roofed building. The details of this figure can be seen clearly in table 4.

Table 4: Details of operating costs and building profits obtained for one year if the green roof concept is fully practiced in the study building.

Building condition	Cost per year (RM)	Building operating cost benefits (RM)
Concrete roof with AC system	9,227,871.60	-
Green roof with AC system + maintenance of green roofed buildings	8,657,245.28 (6,372,812.40 + 2,284,432.88)	570,626.32

Source: Authors (2022

f. Return on investment for the green roof

Referring to item e which is the cost of profit obtained from energy savings for the cooling effect of concrete roof compared to the green-roofed buildings, a plan on the return on investment (ROI) value of green roofs can be calculated roughly. Meanwhile, the information in table 5 submitted by Putrajaya Holding (PJH) which is the final construction cost value for the green roof system of this study building is worth RM8,200,000.00 without being mixed with maintenance costs with the optimal green roof application profit cost value of RM 570,626.32 for a year, period return on investment for the green roof will take 14.4 years. Maintenance cost is subjective in a project because it is subject to the method, level of frequency or care as well as current provisions. Therefore, this matter should be calculated separately and not mixed with the assessment of ROI for the green roof.

Table 5: Details of the final cost of construction and maintenance of a complete green roof system from PJH

Construction / maintenance	Details	Cost (RM)	Total cost (RM)
Green roof system (curve roof + flat roof + glass canopy + observation deck)	Structural & architectural works	6,500,000.00	8,200,000.00
	Landscaping works	1,500,000.00	
	Irrigation sprinkler system	200,000.00	
Maintenance costs	Cost per month	3,000.00 / month	36,000.00 / year

Source: Authors (2022

g. Conclusion

The analysis found if the effect of conduction is assessed on the entire floor level on the second floor, which is under the concrete roof for a year, the energy consumption of 127,233.60 Kw/h is required, while the green roof requires 52,622.40 Kw/h only. The significant difference in the cumulative value of this year with a reduction of 58.64% in energy consumption is additional support that further strengthens the performance and efficiency of the green roofs studied.

In terms of operating costs to cool the entire building for a year, especially during working hours from 06.30 to 18.30, the concrete roof will cost RM 9,227,871.60, and the rain roof is RM 6,372,812.40. Cost savings of RM 2,855,059.20 or 30.94% will be achieved if this green roof concept is applied compared to concrete-roofed.

However, the foundation of the potential success of this green roof requires cost and periodic maintenance by a competent party appointed by the building owner to ensure that all green plants on the roof surface live lushly and consistently. The study estimates the cost of RM 2,284,432.88 per year for the overall maintenance work for the green roof. If the operating cost of cooling the building and the maintenance of the green roof is combined, the total of RM 8,657,245.28 is still below the concrete roof operating cost of RM 9,227,871.60. Here, net savings can be obtained of RM 570,626.32 per year and refers to the allocation of the green roof construction cost of case building of RM 8,200,000.00, a period of 14.4 years is required to obtain investment profit to build this green roof from the net profit of RM 570,626.32.

This study has successfully proved the benefits of applying the concept of green roof in the study building on the value of building cooling energy consumption, cost savings, and operation, as well as return on investment for the period considered relevant. Therefore, it is recommended that the design of the building in the future consider the impact of the green roof design that can benefit the building owner and its users' well-being in the future. In line with current government recommendations, the issue of energy savings and building operating costs can be optimally achieved with building functionality.

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