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ENERGY SAVING AND MAINTENANCE EXPEDITURE OF GREEN ROOF: AN EMPIRICAL STUDY IN JOHOR BAHRU

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ABSTRACT

Introduction of new urban development strategy such as green roof offers promising solution to improve natural environment. Green roof has tremendous benefits primarily reducing energy consumption of a building through cooling effect. However, studies have highlighted green roof implementation associated with high maintenance expenditures. Therefore, this study aims to assess the worth of integrating green roof with building. This study undertook case study approach. Finding proved that green roof able to provide approximately 37% to 40% of energy saving for units positioned exactly below green roof area. However, maintenance cost is 31% to 40% higher than energy saving. The average ratio of cost benefits between maintenance expenditure and energy saving is 1.5: 1. This study has empirically proved that maintenance cost of green roof outweighs the benefits of energy saving. This study contributes significantly in Malaysia green building valuation facet and assist stakeholder to make decision on green roof investment.

Keywords: green roof, cost benefit, energy saving, maintenance, expenditure, monetary

1. INTRODUCTION

The concentration of activities and rapid development of building sectors in urban area causes increase in urban temperature. This phenomenon is known as an urban heat island. An urban heat island is defined as an area in an urban space where the temperature is higher than are the temperatures of the surrounding rural areas (Hung et al., 2006; Peng et al., 2012; Zhou et al., 2017). This phenomenon leads to numbers of adverse effect including deterioration of the living environment, acceleration of air pollution, posing threat to human health, and high electricity consumption for cooling demand (Rosenfeld et al., 1998; Changnon et al, 1996; Rizwan et al., 2008; Vardoulakis et al., 2013; Lowe, 2016).

The increment of total world population in urban area has changed the energy demand aggregate which resulting in additional power generation costs (Santamouris et al., 2014; Miller, 2013). The constant augmentation of surrounding temperature results in increasing energy demand for space cooling through utilization of air conditioning system in building space. According to the International Energy Agency (2017), Malaysia has reported as one of the largest electricity consumer among ASEAN countries after Singapore and Brunei. Malaysia’s overall energy demand for year 2014 is shared by building sector at 39%. It was reported by Energy Commission (2017), the average annual energy growth rate from year 1995 to 2015 for building sector in Malaysia have showed startling increment at 3% to 12%. Henceforth, to address this alarming energy issue, green roof has been introduce as one of the environmentally–friendly new urban development strategy. Green roof consists of several layered systems, namely, the waterproofing membrane, the growing medium and the vegetation layer. Usually green roofs also consist of a root barrier layer, a drainage layer and an irrigation system (Sadineni et al. 2011).

There are two types of green roof setups, which are extensive roof and intensive roof. The difference between these roofs are mainly in the depth of the layer of substrate. Extensive roofs have a thinner layer of substrate which allows low level plants such as sedum or grass to nurture. On the other hand, intensive green roofs have a deeper substrate layer and allow deep rooting plants such as trees and shrubs to grow. Various solution to reduce cooling demand of a building (Mingfang and Xing, 2019; Jiangdong and Mingfang, 2017; Ebadati and Ahyaei, 2018).

However, despite of it tremendous advantageous in reducing the cooling demand, there are few surveys highlighted expenditure issue related to maintaining green roof. Recently, Xi et al. (2019) has conducted a survey to identify the root hindering green roof implementation in urban China. The outcome shows that the main barrier in implementing green roof in urban area is the high maintenance cost. A survey was conducted by Zulhabri et al. (2012) in Klang Valley, Malaysia has reported that 86% respondents agreed that green roof implementation are complicated when it comes to maintenance expenditure. These studies provide evidence that the main concern in implementing green roof is on maintenance expenditure. Therefore, this study purposely conducted to assess the monetary worth of integrating green roof with building using cost benefit analysis between expenditure related in maintaining green roof and the monetary value of annual energy saving conveys by green roof. It was observed that previous studies only focus on perception data through conducting survey among respondents. Therefore, this study investigates the actual energy saving performance and maintenance expenditure of a green roof in use. Therefore, this study classified as a case study research.

2. MALAYSIA CURRENT ENERGY GROWTH

Malaysia is a developing multicultural country located on the South China Sea and lies between 1° and 7° on the North latitude and 100° and 120° on the East longitude. Malaysia is located in the equatorial region which experiences fairly consistent hot and humid throughout the entire year. Being located close to the equator, Malaysia receives abundant of sunshine and high solar radiation. On the average, Malaysia receives sunshine for 6 hours daily. Malaysia has recorded the highest temperature in 2018 at 37.5 Celsius (Malaysia Metrological Department, 2019).

Being a country receiving ample of daily solar radiation creates continuous energy demand for space cooling in order to maintain the indoor comfort. According to report published by Energy Commission (2017), in order to meet the unremitting energy demand, the energy production in Malaysia has experience nearly twice augmentation for the period of past 20 years (1995 – 2015) from 69,983 to 100,721 ktoe. In Malaysia, 95% of electricity generation relies on fossil fuel including crude oil, natural gas, and coal (Energy Commission, 2017). These resources are categorized under non-renewable energy resources and the production processes of transforming these resources into electricity are disparaging the environment and human health. Concurrently, the electricity selling price for the past 15 years (2001 until 2016) recorded by Tenaga National Berhad (TNB) has amplified for residential, commercial, and industrial at 19%, 20%, and 25% respectively. The typical energy breakdown for average Malaysian buildings shows that air conditioning responsible for the highest energy consumption of a building at 50%. Meanwhile, another 25% for lighting and 25% for small power equipment (Building Sector Energy Efficiency Project – BSEEP, 2017).

3. ENERGY SAVING CONVEYS BY GREEN ROOF

Green roofs are generally built to enhance energy efficiency of buildings by preventing the penetration of solar heat into the building through the rooftop surface (Chen, 2013). Green roofs were verified to provide a cooling effect by reducing the indoor air temperature (Ismail et al., 2016). Shazmin et al. (2019) has conducted a research in Malaysia to compare the monetary energy saving between two vegetated based green components including green roof and green wall. The study have proved that the integration of green roof able to provide annual monetary energy saving at around MYR 139. An experimental test and simulation was conducted by Santamouris et al. (2007) to investigate the performance of green roofs in reducing cooling and heating demand during summer and winter respectively. The experiment was conducted on a nursery school located near the center of Athens. The findings showed that the green roof system provided significant savings for cooling loads during summer but not during winter, where the findings on the heating load were insignificant. The study revealed that during summer, green roofs conveyed higher annual cooling load reduction on non-insulated buildings compared to insulated buildings at 15% to 49% respectively, for the whole building. The cooling load yielded even higher amounts of reduction for the first floor, which was positioned precisely under the green roof, at up to 76%. Hence, this result explicitly proved that the installation of green roofs provided optimum benefit in energy savings in terms of cooling demands for building unit positioned precisely under the green roof (Santamouris et al., 2007).

Another study by Niachou et al. (2001) was conducted to investigate the thermal properties as well as the energy efficiency of a green roof system upon a building in Athens. The study indicated that green roofs on non-insulated buildings provided better thermal performance compared to well-insulated buildings. It is evident that the annual energy savings for green roofs on non-insulated buildings was at 37% and had the potential to increase to 48% (Niachou et al., 2001).An experimental study was conducted upon a green roof system on top of a low-rise five storey commercial building. The study was conducted under the hot and humid climate of Singapore. The study proved that the installation of green roofs could result in annual energy consumption savings of up to 15%. The study also indicated that for space peak cooling loads, green roofs are able to provide savings of 17% to 79% (Wong et al., 2003). Jiangdong and Mingfang (2017) have performed a building simulation in Shanghai during summer season. The simulation result indicated the integration of green roof able to reduce approximately 26.7% of cooling load demand of a building. In Beijing, China, another building simulation was conducted by Lin and Mingfang (2017). The experiment was performed during the hottest month of the year. The result shows that green roof may reduce 24.6% of cooling load of a building.

Latest research was carried out by Mingfang and Xing (2019) in Shanghai, China. This study was perfomed using real case study. The result showed that the integration of green roof able to provide reduction for cooling load at 14.7% annually. Another study was conducted in China by Zhen et al. (2017). The building simulation result indicated that green roof able to covey between 27.7% and 35.8% of annual cooling load reduction during the hottest month of the year. Meanwhile, during summer season in Athens, Greece, it was found that the integration of green roof on building envelope able to provide cooling load reduction at 15% to 49% (Santamouris et al., 2007) and 37% to 48% (Niachou et al., 2001). In Singapore, a building simulation was conducted by Wong et al. (2013) on green roof. It was found that green roof able to provide 15% cooling load reduction for a building. Therefore, it was found that the integration of green roof able to provide approximately 14.7% to 49% cooling load reduction per annum. The summary provided in Table 1.

Table 1: Summary of annual energy saving by green roof

Annual energy saving (%)		Location	Authors
Type of energy saving	**Percentages of energy saving**		
Cooling load	23	Tehran	Ebadati and Ehyaei (2018)
Cooling load	26.7	Shanghai, China	Jiangdong and Mingfang (2017)
Cooling load	15 – 49	Athens, Greece	Santamouris et al. (2007)
Cooling load	37 – 48	Athens, Greece	Niachou et al. (2001)
Cooling load	15	Singapore	Wong et al. (2003)
Cooling load	24.6	Beijing, China	Lin and Mingfang (2017)
Cooling load	14.7	Shanghai, China	Mingfang and Xing (2019)
Cooling load	27.7 – 35.8	Suzhou, China	Zhen et al. (2017)

4. GREEN ROOF MAINTENANCE

Green roofs require maintenance, and, above all, irrigation. Indeed, the most important principle of functioning is the evapotranspiration of the water, which induces the evaporative cooling, that dissipates the sensible load connected to the solar radiation by means of a latent heat transfer. This phenomenon implies cooling energy savings. However, Muhammad et al. (2018) has highlighted that research on green roof maintenance is very limited. There are several studies that have been highlighted the expenditure issue related to green roof maintenance. Recently, Xi et al. (2019) has conducted a survey among professional bodies including building industries, research centers, universities, and public in urban area in China. The survey was conducted for the purpose to identify the root hindering green roof implementation in urban China. The surveys has listed 27 lists of potential barriers in implementing green roof. The outcome shows that the first ranked main barrier is high maintenance cost. The study confirms that the integration of green roof will increase the maintenance cost which includes the gardener cost, continuously changing plants, pesticides, water usage, facility cleaning and repair.

Meanwhile, a survey on green roof maintenance was conducted by Zulhabri et al. (2012) in Klang Valley, Malaysia. The survey was conducted among 30 maintenance managers of green roof of stratified residential building in the city of Kuala Lumpur. The result has reported that 86% respondents agreed that green roof implementation are complicated when it comes to maintenance expenditure. The study has highlighted three major issues mostly occurred during maintenance process of green roof including leaking, plant loss, and inadequate drainage. Leaking is considered as a major problem that occur in maintaining green roof. Zulhabri et al. (2012) has ranked the maintenance criteria for green roof practice in Malaysia. The result showed that drainage, water proofing, and irrigation are the most important maintenance criteria for green roof.

Ines et al. (2018) has proved that according to the green roof financial analysis, the maintenance cost of green roof will provide negative Net Present Value (NPV). The study shows that type of green roof is the key parameter. Intensive green roof was found to have better capital recoveries than extensive type of green roof. Moreover, the study shows that flat roof have lower maintenance and replacement cost compared to slope roof. According to Muhammad et al. (2018), green roof require a proper maintenance during the different time interval. It need a regular irrigation and fertilization to achieve optimum benefits from the green roof. Vivian et al. (2016) has conducted a survey in Hong Kong among professional including architects, engineers, surveyors, landscape architects, property management staff, contractors, environmental protection officer, and academician. The survey was conducted to determine the cost effectiveness of green roof system. The survey indicated that maintenance cost are the major considerations in most green roof application. It was also stated that maintenance issues regarding green buildings are leakage and irrigation. The study revealed that some of the respondents of the study are not willing to pay high maintenance cost for green roof.

5. METHODOLOGY

This study investigates the actual energy saving performance and maintenance expenditure of a green roof in use. Therefore, the study can be classified as a case study research. Case study approach allows an in depth investigation of contemporary phenomena over which the researcher has little or no control (Yin, 2009; Saunders et al., 2009).The case study is located in the major city of Johor Bahru in Malaysia. The case study which was investigated in the study is stratified residential building located in the city of Johor Bahru known as Strait View 18 Apartment. This apartment has 17 floors and total unit of 47. This apartment is not certified by any green accreditation body as the accreditation is a voluntary process. However, the apartment is integrated with extensive green roof on the top flat roof area which covers more than 50% of the rooftop area. According to Green Building Index (GBI) guideline, to be certified as a green roof, it must be covered at least 50% of the total roof area. Figure 1 is a green roof view for the case study.

Data Collection and data analysis

The longitudinal data for the past building energy usage were collected from the electricity provider known as *Tenaga Nasional Berhad (TNB)* located in Jalan Yahya Awal, Johor Bahru. The data of electrical usage of each unit were collected in year 2019 for the past four consecutive months from January until April as tabulated in Table 2. The data were collected from all units positioned precisely under the green roof which is at 16th floor and units located at the lower floors which is at third floor. This is in order to calculate the amount of energy saving convey by green roof through comparing the amount of electrical usage between the top floor and lower floor. This theory has been proved by Santamouris et al. (2007). According to him, the installation of green roof provided optimum benefit in energy savings in terms of cooling demands for building unit positioned precisely under the green roof. The actual data were provided in Kilowatt per month (kWh/month). Henceforth, to convert the amount of energy usage (kWh) into monetary value, the amount of energy in kilowatt unit is multiplied with the current electricity tariff of residential as imposed by Malaysia electricity provider. Building tariff rate as being tabulated in Table 3.

Electrical monetary saving (MYR) = (Average upper floor unit energy usage x tariff) – (Average lower floor unit energy usage x tariff)

Meanwhile, the data on maintenance expenditures were collected from the building manager using informal interview session. The data contain information about the actual cost that involves in maintaining green roof. The data were collected in year 2019 for the past four consecutive months from January until April. These data were analyzed using cost benefit analysis. Arrow et al. (1996) explained that cost benefits analysis has been widely recognized as a useful framework for the purpose of assessing the positive and negative aspect of prospective action and policies and also making the economic implication alternatives an explicit part of decision making process.

Figure 1: Green roof view of case study

Table 2: Electricity consumption for upper and lower floor of case study

Unit Number	**Electricity usage per month (kWh)**			
	January 2019	**February 2019**	**March 2019**	**April 2019**
01-16A	1931	1774	2254	2103
02-16B	1511	1689	1399	1592
03-16A	1881	1543	1751	1406
04-16B	1874	2075	2374	2232
01-3A	3257	3158	2603	2972
02-3B	2987	2434	3268	3125
03-3A	3109	3252	3084	2983
04-3B	2584	3019	3305	2619

Source: Tenaga Nasional Berhad (2019)

Table 3: Malaysia electricity tariff for residential

Domestic Tariff (kWh/month)	**Rates (RM/Watt)**
First 200 kWh (1 - 200 kWh)	0.218
Next 100 kWh (201 – 300 kWh)	0.334
Next 300 kWh (301 – 600 kWh)	0.516
Next 600 kWh (601 – 900 kWh)	0.546
Next 900 kWh (901 kWh onwards)	0.571

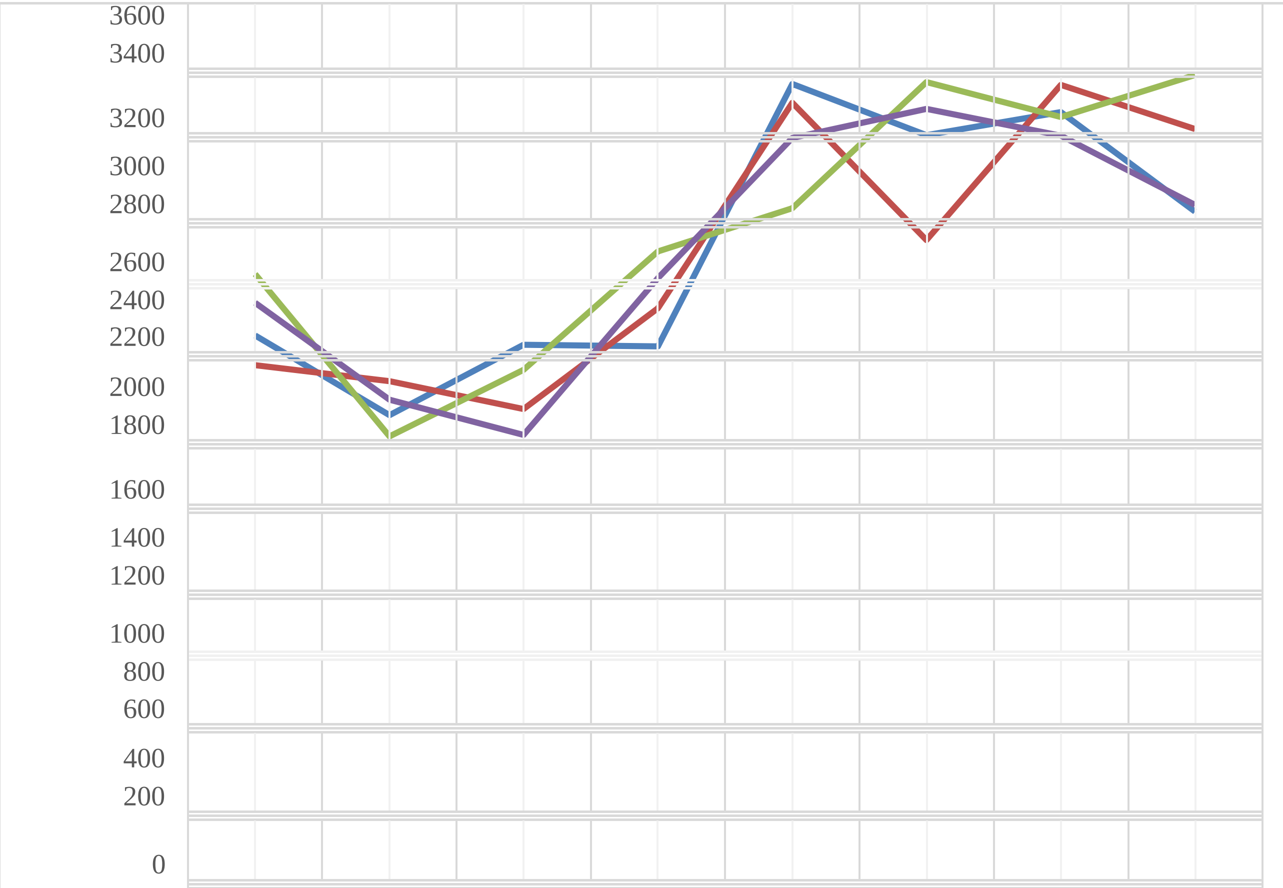
Source: Tenaga Nasional Berhad (2019)

6. FINDINGS AND DISCUSSIONS

Energy saving by green roof

The findings show apparent differences between average electricity consumption between units that positioned precisely below green roof area and units at the lower area. The finding shows units that position right below rooftop area which is at 16th floor have less energy consumption compared to units at lower level which is at third floor (refer figure 2). It was found that the average electricity consumption for upper unit is between 1770 to 1945 kWh per month. Meanwhile, the lower unit which position far from the green roof area have higher average energy consumption between 2925 to 3065 kWh per month. Lower unit is consider having less effect of cooling convey by green roof compared to units that place under the green roof area. This finding aligned with Santamouris et al. (2007). Within the context of this study, the finding has empirically proved that the integration of green roof able to provide energy saving at approximately around 37% to 40%. February 2019 recorded the highest monetary saving in electrical consumption is at MYR658 per month. Meanwhile, April 2019 recorded the least monetary energy saving contributes by green roof at MYR 573. This specified that building integrated with green roof provides extra benefits to the upper unit residents by providing around MYR 573 to MYR 658 saving in monthly electricity compared to unit that positioned at the lower floor (refer Table 4). This findings contributes significantly in the valuation facet of green building especially in Malaysia.

Figure 2: Monthly energy consumption for upper unit (16th floor) and lower units (3rd floor)



	01-16A	02-16B	03-16A	04-16B	01-3A	02-3B	03-3A	04-3B
Jan-19	1931	1511	1881	1874	3257	2987	3109	2584
Feb-19	1774	1689	1543	2075	3158	2434	3252	3019
Mar-19	2254	1399	1751	2374	2603	3268	3084	3305
Apr-19	2103	1592	1406	2232	2972	3125	2983	2619

Table 4: Monetary electricity saving by green roof

Unit Number	Actual electrical usage per month (kWh)			
	January 2019	**February 2019**	**March 2019**	**April 2019**
Upper unit - 16th floor (precisely below green roof area)				
01-16A	1931	1774	2254	2103
02-16B	1511	1689	1399	1592
03-16A	1881	1543	1751	1406
04-16B	1874	2075	2374	2232
Average usage per month (kWh) (A)	**1799**	**1770**	**1945**	**1833**
Lower unit -3rd floor				
01-3A	3257	3158	2603	2972
02-3B	2987	2434	3268	3125
03-3A	3109	3252	3084	2983
04-3B	2584	3019	3305	2619
Average usage per month (kWh) (B)	2984	2966	3065	2925
Total electrical saving (kWh) (B – A)	1185	1196	1121	1092
Monetary saving in electrical usage per month (MYR)	613	658	629	573
Percentage of energy saving per month (%)	40%	40%	37%	37%
MYR – Malaysia Ringgit				

Maintenance expenditure of green roof

The findings showed there are five attributes related to maintenance expenditures of green roof. These including labour, pest and disease control, plant and vegetation, water irrigation, and fertilizer. The monthly cost for the maintenance of green roof at MYR950. According to the interview session, labour constitutes the highest cost in maintaining green roof. It contributes to 74% of the total cost of maintenance. The second highest cost is water irrigation cost at MYR100 per month which contributes to 11% of the total cost of maintenance. Meanwhile, pest and disease control, plant and vegetation, and fertilizer contribute to 15% of the total cost of maintenance.

Table 5.0: Green roof maintenance expenditures

Maintenance expenditure attributes	**Actual maintenance cost for green roof (MYR)**			
	January 2019	**February 2019**	**March 2019**	**April 2019**
Labour	700	700	700	700
Water irigation	100	100	100	100
Pest and disease control	50	50	50	50
Fertilizer	50	50	50	50
Plant and vegetation	50	50	50	50
Total maintenance cost per month (MYR/month)	**950**	**950**	**950**	**950**

Cost benefit of green roof

This study has revealed maintenance cost has outweigh energy saving benefits conveys by green roof. This finding is supported by studies conducted by Xi et al. (2019) and Zulhabri et al. (2012). Furthermore, this study provides the actual surfeit of maintenance cost. The analysis showed maintenance cost is around 31% to 40% higher than the energy saving provided by green roof. This is equal to MYR 292 to MYR 377 per month. Figure 3.0 displays the highest energy saving in February 2019 at MYR 658 unable to compensate the maintenance cost of green roof at MYR 950. The average ratio of cost benefits between maintenance and energy saving is 1.5:1 (refer table 5). This ratio describes the maintenance cost is 1.5 higher than the energy saving provided by green roof. This indicated that the benefits of energy saving alone is unable to compensate the maintenance cost of green roof. However, there are numerous of other green roof benefits that is quantifiable into monetary value as such storm water reduction, noise reduction, and property value increment.

Figure 3.0: Maintenance cost and energy saving

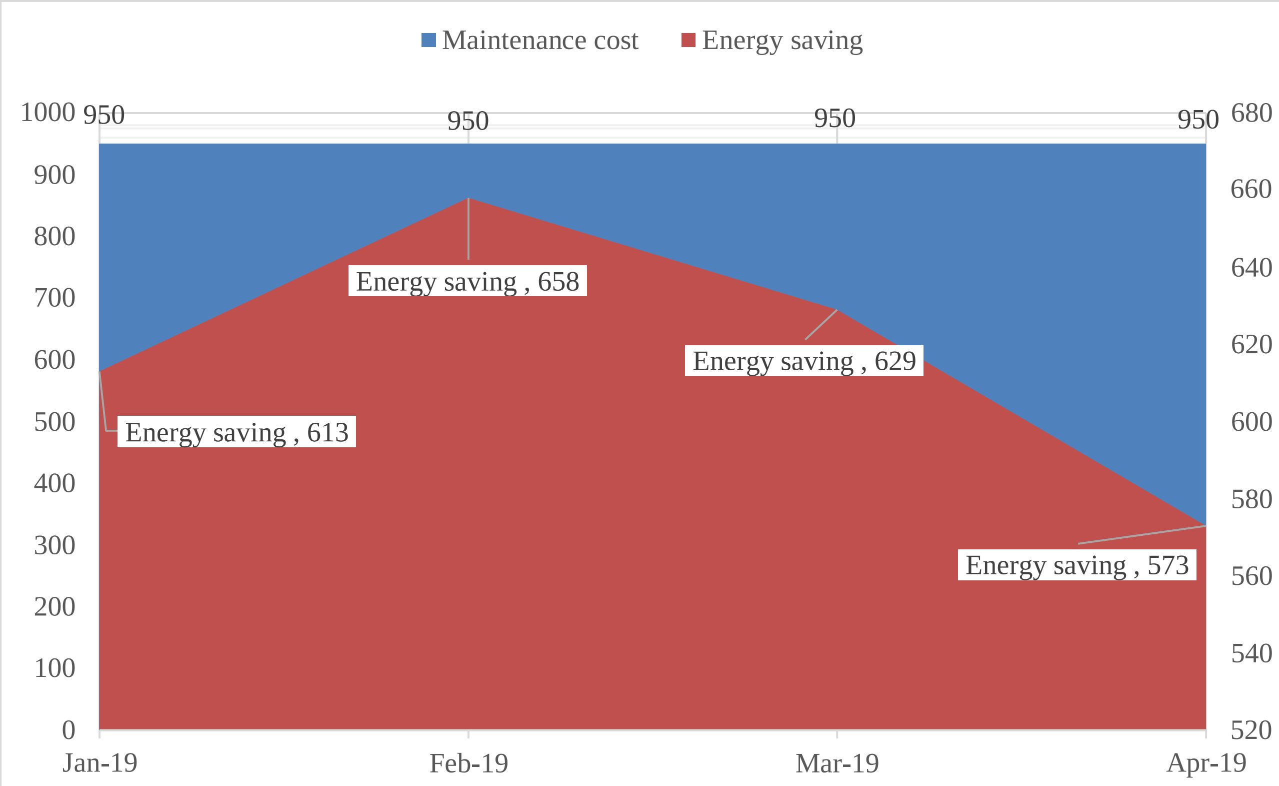


Table 5.0: Green roof cost benefits analysis

Attributes	**January 2019**	**February 2019**	**March 2019**	**April 2019**
Maintenance cost (MYR)	950	950	950	950
Energy saving (MYR)	613	658	629	573
Excess in maintenance cost (MYR)	337	292	321	377
Excess in maintenance cost (%)	35%	31%	34%	40%
Cost benefit ratio	1.5 : 1	1.4 : 1	1.5 : 1	1.6 : 1

7. CONCLUSIONS

Briefly, the implementation of green roof provides numerous benefits primarily on energy saving. This study has proved that the integration of green roof is highly effective for units positioned exactly below green roof area rather than lower floor unit. This study has supported the findings of other studied which have proved that the maintenance cost of green roof is relatively high when compared to energy saving benefit. However, there are numerous of other green roof benefits that is quantifiable into monetary value as such storm water reduction, noise reduction, and property value increment. Therefore, addressing the limitation within the scope of this study, future study should include these benefits in conducting cost benefit of green roof. The inclusion of other green roof benefits may outweigh the maintenance cost of green roof. This study contributes significantly in the valuation facet of green building especially in Malaysia and also provide parameter to assist stakeholder to make decision to invest in green roof.

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