

COST BENEFIT ANALYSIS IMPLEMENTING GREEN WALL AT COMMERCIAL BUILDING ROXY HOTEL PADUNGAN, SARAWAK, MALAYSIA

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ABSTRACT

The building sector is consuming high energy consumption which could lead to the negative impact to the environment. Building and property are partly responsible for this increment. Several efforts have been conducted to overcome this issue. Integrating green wall on building has proved to reduce building annual energy consumption. Although there are many benefits in annual energy savings, several studies have shown that the implementation of green walls is associated with high maintenance costs. Therefore, the aim of this research is to assess the worth of implementing the green wall through comparing the maintenance cost and its energy saving benefits. There are three main objectives outlined in this research: 1) To identify percentage of green wall efficiency in reducing building energy consumption; 2) To analyse the monetary electricity saving due to the green wall implementation on building; and 3) To compare between maintenance cost and annual energy saving using cost benefit analysis. This research is conducted at Roxy Hotel Padungan, Kuching, Sarawak, Malaysia. It has been found that the benefit of green wall is higher than cost of the green wall by using cost benefit analysis. The value of energy saving in the building is RM3.00 per square foot meanwhile the value of maintenance cost is RM2.70 per square foot. The ratio of cost benefit analysis between annual energy saving and maintenance cost is 1:1.1. This research is significant for the investor, developer, and property owner to make decision in implementing green wall on building.

Keyword: *Green wall, commercial green building, cost benefit analysis, annual energy saving, maintenance cost.*

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1. INTRODUCTION

Global warming nowadays known as an international environmental issue is getting important as it has adverse effect to the environment and humankind. In recent years, the climate change and global warming issue are being addressed at international, national, and local level. At the late of December 2019, the new COVID-19 virus has spread to the entire planet like a fire and has lowered the quality of human life. This pandemic has affected all lives and prompted more individuals to stay at home for safety. This is where green building plays a part in making people's lives more comfortably and at the same time giving the world a positive influence. Before the advent of antibiotics, ventilation and daylight were considered to be important safeguard against infection, from the history of the past pandemic.

Oleiwi, et al. (2014) stated that green building is a building with modern architectural concept which focuses on the environment by reducing energy consumption, materials and resources and also minimize the impact of construction. Furthermore, green buildings are designed to harmonise with the local climate, traditions, culture, and the surrounding environment. Green wall is a vertical greening typology, where a vertical built structure is intentionally covered by vegetation (Medi et al., 2017; Gunawardena et al., 2017). Green wall systems can maximise the functional benefits of plants to buildings performance (Lundholm, 2006). In addition, greening systems can also make part of a sustainable strategy (Ghaffarian et al., 2013) of urban restoration and building retrofitting (Saadatian et al., 2013). This shows that green wall can be one of the solutions in improving the quality of human life.

2. LITERATURE REVIEWS

2.1 Green Building

Green building is a structure of green development, the process, innovation, and design that inspire the worldwide (World Green Building Council, 2013). The main principles adapt is to be responsible towards environment and resources consumption efficacy reflected through as early as the design construction stages up to the building processes and through the life cycle of the building. According to U.S. Environmental Protection Agency (2003), green building is aimed to reduce the negative impacts of properties development to the environment and residents in the earth by being resources and energy efficient when recycling usable building materials to reduce waste and emissions.

2.2 Green Building Benefits

Kibert (2016) stated that sustainable beneficial environmental and economic advantages could be achieved by practising green building. This statement shows that green building was one of practise that help to achieve sustainability in the environment, economy, and society (Anuar et al., 2012; Mohammad et al., 2014).

Table 1: Benefit of Green Building

BENEFITS OF GREEN BUILDING	
Financial	• Longer economic life of the facility • Lower employee turnover • Staying ahead of regulations • Lower litigation risks because of improved indoor air quality • Lower health related costs such as insurance premiums • Lower absenteeism/ increase productivity • Optimize life cycle economic • Improve employee productivity and satisfaction • Reduce life cycle energy costs • Decrease operating costs
Environmental	• Protect natural resources • Decrease solid waste • Enhance and protect ecosystem • Develop water and air quality
Health and Community	• Set example in the community • Contribute the overall quality of life • Minimise strain on local infrastructure • Enhance occupant comfort and health • Improve air, thermal, daylight and acoustic environments

Source: Ashuri and Durmus-Pedini (2010)

2.3 Green Rating System

Green building rating system, as defined by Nguyen and Altan (2011), is a tool that the industry uses to assess, enhancement and promotion of sustainable development. According to Altin (2017), green building rating system is transforming the construction industry by focusing on high-performance, energy-efficient, economical, and environmentally friendly buildings. Green building rating system plays a crucial role in supporting this transformation (Pandey, 2014). There are two rating tools in green rating system which are Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) (Awadh, 2017; Cole & Jose, 2013; Reed et al. 2009; Rivera, 2009; Lee & Burnett, 2008; Kawazu et al. 2005).

2.4 Green Building Index (GBI)

Green Building Index (GBI) is a rating system for benchmarking that incorporates best practices in environmental performance and design that are internationally recognised. GBI has highlighted the eco-friendly characteristics or criteria that have to be or have to be incorporated into industry practice. Mun (2009) claimed that GBI is officially established on May 2009 and developed by Association of Consulting Engineers Malaysia (ACEM) and Malaysia Institute of Architects (PAM). There are two categories of GBI which are GBI residential rating tool and non-residential rating tool. Green Building Index Sdn. Bhd. (GSB) is the agency responsible for the management of this assessment rating system and certification.

Table 2: GBI Classification

RATING	POINTS
Certified	50 - 65
Silver	66 - 75
Gold	76 - 85
Platinum	86 - 100

Source: GBI (2013)

Basically, GBI rating system was created based on the Singapore Green Building Index and Australian Green Star System. GBI consist of six key criteria for rating the Green Building in Malaysia (Md. Hussin et al., 2013) which state at table 3.

Table 3: GBI Rating Criteria

CRITERIA	DESCRIPTION
Energy Efficiency	i. Minimise solar heat gain and capture natural lighting to reduce energy usage. ii. Practice regular maintenance, proper testing, and commissioning. iii. Use renewable energy. iv. Optimising building orientation through design.
Indoor Environmental Quality	i. Improving indoor air quality, acoustics, visual comfort, and thermal comfort. ii. Materials with a low volatile organic compound content should be used. iii. Utilise high-quality air filtration and proper temperature, movement, and humidity regulation.
Sustainable Site Planning and Management	i. Appropriate site selection with community facilities, planned public transportation connections, open spaces, and green areas enable redevelopment of existing sites and brownfield developments. ii. Implementation of proper management practices during construction, reduce the burden on established capacity for infrastructure and management of storm water.
Material and Resources	i. Promoting the use of renewable and recycled forms of environmentally friendly products ii. Implement the right management of waste with storage and collection. iii. Encourage the re-use of recycle materials, formwork, and waste.
Water Efficiency	i. Water efficiency can be described as the usage of water-saving fittings, rainwater harvesting system and water recycling.
Innovation	i. The innovation design and initiatives must be aligning with GBI's objectives.

Source: Md. Hussin et al. (2013) and World GBC (2013)

2.5 Green Component

Green building components are described as being the combination of green components deriving from green criteria of green rating tools with those of building (Zuo & Zhao, 2014). The main advantage is to enhance occupant health in order to improve indoor environmental quality (IEQ) and healthier living space, energy savings and greater long-term cost savings or profits and most importantly the reduction of greenhouse gas emissions and hence the impact of buildings on the environment (McGraw-Hill Construction, 2013).

Many studies have concluded that green building components provide a great opportunity for stakeholders, including developers, contractors, and policymakers, to minimise the environmental impact of the construction industry (Carter & Fowler, 2008). A broad range of green building elements, such as green-roof technologies (GRHCC, 2003); waste management technologies (Shen et al., 2009); solar power systems (Huang & Wu, 2007); and technologically improved heating, ventilation, and air-conditioning systems (UNEP, 2003).

2.6 Green Wall

Green wall is a vertical garden appended to the interior or exterior of a building. Vertical greening, also known as facade greening, green wall, planting wall, vertical garden, living wall, or ecological wall, where it is basically a building coating system and revitalisation (Kingsbury & Dunnett, 2008). At a building scale, green wall systems can be used as a passive design solution (Perez et al., 2011) that lead to contribute to the buildings sustainability performance (Eumorfopoulou & Kontoleon, 2009). Randy et al. (2020) noted that the integration of the living, organic system characteristics by green wall could change an inorganic and lifeless structure of building into a new type of 'living' architecture.

The common term to refer to all forms of vegetated wall surfaces is green wall. Since the era of the Hanging Gardens of Babylon and the Roman and Greek Empires arise, traditional green wall techniques are historically known. The Hanging Gardens of Babylon has given an impact on the evolution of the green wall because later, from Scandinavia to Japan, numerous civilisations used climbing plants to cover building.

2.7 Green Wall Classification

Green walls can be subdivided in two main systems which are green facades and living walls (Kohler, 2008; Manso & Castro-Gomes, 2015).

a. Green Facade

Green facades are implemented for the purpose of climbing or hanging plants along the wall. Dunnett et al., (2008) stated that green facade is the plants that hanging in certain height, can grow upwards on the vertical surface, like traditional examples, or grow downward on vertical surface. Green facade can be anchored to existing walls or built as freestanding structures such as columns or fences. According to Randy (2020), self-

clinging plants such as English Ivy have commonly been used to create green walls. There are two types of green facade which are direct green facade and indirect green facade. The differences between these two types of green facade are easy to differentiate them. The direct green facade is directly attached to the wall meanwhile indirect green facade presents is a structural support for the growth of vegetation.

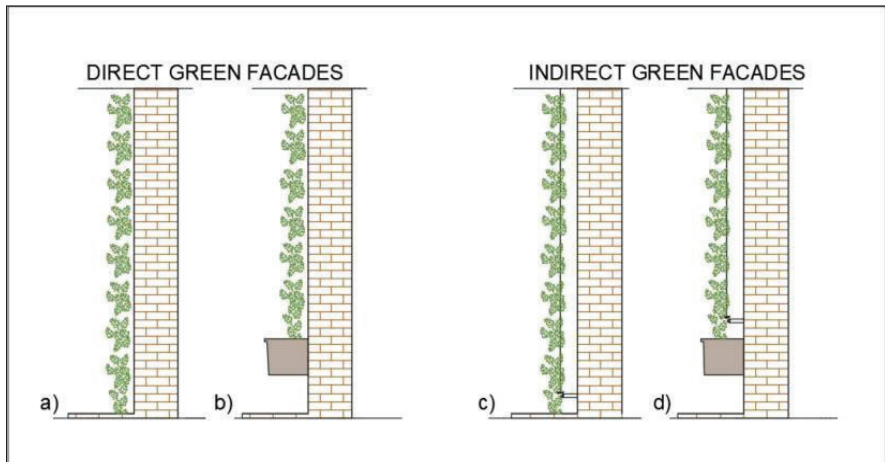


Figure 1: Direct Green Facade and Indirect Green Facade

b. Living Walls

Living wall system uses lightweight and permeable screens to which plants are added individually. It involves the installation of a frame to the wall, with a void in between them. This frame not only holds the base panel, but also protects the wall from moisture. Palermo & Turco (2020) mentioned that there are two types of living wall which are continuous living wall and modular living wall. Continuous living wall supported by a base panel and directly attached to a supporting structure which consisting of a frame indirectly fixed to the wall. This type of system is mainly based on hydroponic technique. Koumoudis (2010) stated that green wall is a modular living wall system have a component that in certain dimension, which includes the growing media reinforcing the plant's growth. Each component is held by a corresponding structure or is directly mounted to the vertical surface.

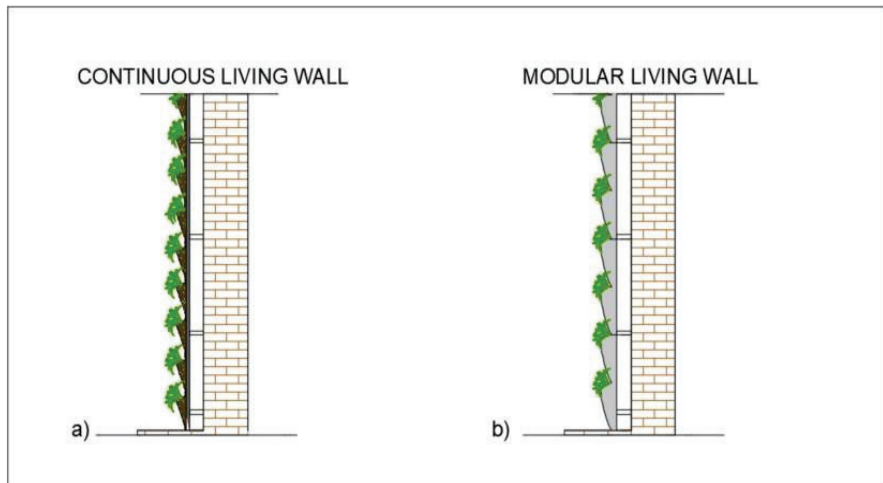


Figure 2: Continuous Living Wall and Modular Living Walls

2.8 Green Wall Benefits

a. Enhance Cities Image

Green wall has a therapeutic effect by inducing a psychological wellbeing through the presence of vegetation, enhance cities image (Theodoridou et al., 2012), and increase property value (Ichihara, 2011). There were the work of Patrick Blanc, a botanist and researcher. The original design of the 25m high wall, and the building is constructed over 237 plants and covers the original graffiti that covered the concrete wall. The green wall was an additional that improve beautifies of the walls on the street that could be enjoyable sight to see.

b. Urban Biodiversity

Covering buildings with vegetation will enhance the urban environment by contributing to urban biodiversity (Francis, 2011). Furthermore, green colour has been proven as one of the colours that can enhance vision, boosts appetite, stimulate healthy living and relaxed mind and our body.

c. Manage Storm Water

Green wall helps to manage storm water (Schmidt et al., 2003), improve air quality reduce temperature (Santamouris, 2014) and mitigation of the heat island effect (Gago, 2013). Green wall can manage of storm water because green wall has a layer of plant material that could potentially absorbs water like a sponge. They capture water when it rains, slowly releasing it through evaporation and plant use.

d. Complementary Thermal

Implementation of green wall on seasonal country will bring benefits in aspect as a

complementary thermal (Sadineni et al., 2011). Cheng et al. (2010) has conducted an experiment approach to assess the effect of vegetation on the thermal performance.

e. Acoustic Protection

Green wall enables to provide an acoustic protection (Renterghem et al., 2013). Acoustic protection is an application of soft or porous material that were used to protect individuals against undesirable sounds and noises. Acoustics protection is employed not in physical health aspect but also in physiological wellbeing. Wong et al. (2010), has conducted a study and the study shows that the greater greenery coverage, the higher frequencies of sound observation on the building.

f. Air Purification

Green walls are the plant that lives on the wall. Planting trees and plants is a common way to enhance air quality. Every square metre of greenery removes at least 300g (10 oz.) of carbon dioxide and in one year, and a 50 square feet green wall can consume as much carbon dioxide as a 14-foot tree ("The Benefits of Living Green Walls", 2014).

g. Positive Environment

Green wall can be directly linked to the sense of wellbeing, positive moods, enhance learning and more efficient decision-making on complex tasks. Green wall has also been known to enhance social relationships between neighbours.

2.9 Maintenance of Green Wall

The installation process of green walls, including climbing species, are more cost-effective, but have limits on the diversity of plants. These systems present difficulties in ensuring vegetation continuity when there is a need for plant replacement. Some climbing plants on the green wall also need guidance during plant growth to ensure that the plant can cover the entire surface of the wall. Some of the climbing plants can bring damage to buildings surface by destroying it with their root sand entering into the voids or cracks in the wall.

Randy et al. (2020) noted that the installation cost of living wall is higher than green facade. This is because the living wall require much more material than green facade, therefore the costs is higher. However, in term of maintenance cost, living wall provide several benefits. In certain unexpected situation, living wall panels can be easily replaced and provide more rapid renewal of vegetation (Manso & Catro, 2015; Besir et al. 2013).

2.10 Annual Energy Saving of Green Wall

Several researches have shown that green wall have empirically proven to convey annual energy saving through reduced energy cooling demand of building (Niachou et al. 2007; Santamouris et al., 2007; Wong et al., 2010; Jaafar et al., 2013; Coma et al., 2017; Perez et al., 2011).

Kontoleon & Eumorfopoulou (2010) conducted study on the influences of the orientation green wall on the thermal performance of the building. The study shows that green wall is able to provide annual cooling load with 18%. The study modelled on a green wall with 20 cm thickness and places on four direction which is north wall, south wall, east wall, and west wall.

Wong et al. (2010) has conducted an experimental study to shows the thermal performance among several configurations of vertical green facade under the hot and typical humid climate of Singapore. The study shows that grid and modular panels are the best green wall configuration that could use to reduce temperature in hot and humid climate. The study also concludes that green wall on the building is able to provide annual energy savings with 18% to 34%.

Green living wall reduce indoor air temperature under hot and arid climate of Abu Dhabi. The study was conducted on school building and using plastic planter boxes with dimension of 30 cm x 30 cm x 25 cm. The green wall was permanently attached on the wall. The study shows that the green wall is enabled to provide 20% of energy savings for cooling.

Coma et al. (2017) also conducted a study which title of comparing the thermal performance of two experimental vertical greenery system which is green wall and with evergreen species and green facade with deciduous creeper plants. The study shows that the potential of energy saving by green wall is at 58.9% with evergreen species and 33.8% for double green facade. Both of the green wall has its own energy saving which is beneficial to the building.

Perez et al. (2011) also investigated a green wall that has been implemented on building with Mediterranean continental climate. The experimental shows that green system as a passive system and obtaining an energy saving up to 34% with a leaf area index of 3.5 to 4. Furthermore, because of the shadow effect of green facades on the East and West orientations was realistic, the result reveals that this, as well as the South orientation they also should be considered on implementing green wall.

2.11 Cost Benefits Analysis

Shim & Siegel (1989) claimed that cost benefit analysis could assist to justify the result of alternative taken is worth by taking the estimated cost. Other than that, according to Mott Linn (2011), cost benefits analysis is significantly helpful in saving money once the decision is taken whether want or not to build an outsized cost. Cost benefit analysis also used to show the transaction cost of theory to analyse all the costs and benefits as stated by Fan et al. (2018).

The cost of integrating sustainable design elements are relatively small but still give noticeable impacts on the overall cost. The environmental impacts of projects should be into the cost benefits analysis framework to improve the quality of decision making (Fan et al. 2018).

3. METHODOLOGY

This research embarks on a literature review and qualitative method approach using semi-structure interview. It is acted as an approach for data collection and data analysis will be used to achieve the outcomes of the study.

3.1 Data Collection

There are two types of data, which are primary data and secondary data. The primary data is the data collected by interview and paper from the specialist and expert. Data collected from some literature reviews and previous studies are the primary data. Literature review gives general understanding of green building and green wall, identifying what is green wall and the evolution of green wall. Literature review expose the needs to identify the benefit of green wall which is the energy saving that convey by the green wall on a building and the explanation from the previous research proves that maintenance cost of the component is high.

Secondary data gained from interview conducted on respondent. The interview is conducted to extend the knowledge about green wall. A semi-structure of interview is conducted to the manager in the buildings and management team or the landscape architecture to get their point of view to get the data about the attributes related in maintaining green wall and then manage to get the cost of the attribution.

3.2 Data Analysis

The main purpose of conducting the data analysis is to achieve the research objective and to support the conclusion of a research. In this research, the annual energy saving by green wall has been obtained by referring to the finding of the previous study. The literature review will provide a list of number regarding the contribution of green wall in reducing energy on the building.

The second objective is to analyse the monetary electricity saving due to green wall implementation on building. This objective obtained from comparing two attributes which are maintenance cost of the green wall and annual energy saving by green wall. The data will be simplified to form a ratio.

For the last objective is cost benefits analysis can be form by compare the cost and energy saving. The number will be smaller due to the calculation will be in per square foot. The number will be transformed to ratio and the ratio will determine which attribute has a bigger number.

4. RESULT AND DISCUSSION

4.1 Percentage of Green Wall Efficiency in Reducing Building Energy Consumption

The first objective to this research is to identify the percentage of green wall efficiency in reducing building energy consumption. This objective is the most important part of this study so

that actual percentage of reducing energy consumption by green wall could be achieved. The percentage is obtained by referring to the literature review as shows at Table 4.

Table 4: Annual Energy Saving of Green Wall

GREEN WALL ANNUAL ENERGY SAVING	AUTHORS
18%	Kontoleon and Eumorfopoulou (2010)
18% - 32%	Wong et al. (2010)
20%	Hanggag et al. (2014)
33.8%	Coma et al. (2017)
34%	Perez et al. (2011)

4.2 Monetary Electricity Saving Due to the Green Wall Implementation on Building

The second objective of this research is to analyse monetary electricity saving due to green wall implementation on building. The finding of the annual energy saving has been proven on Table 5 that has shown the calculation of the annual energy saving of the green roof using data, which is the electricity bill, obtained from Tenaga Nasional Berhad (TNB), Malaysia. The data obtained from the ground floor and the first floor of the building shown in the Table 5 is used to identify the effectiveness of the implementation of the green wall through the energy saving, since the first floor has more exposure to the benefit of the green wall than ground floor.

Table 5: Electricity Used in Ground and First Floor of Roxy Hotel Pandungan

Storey	kWh	RM/Month	RM/Year
Ground Floor	3640	2,063.84	2,4766.08
First Floor	3057	1,710.97	2,0531.64

From this, the energy saving that has been calculated is shown as Table 6.

Table 6: Energy Saving

Storey	RM/Year	Size of Wall (sqft)	Electricity Per Square Foot (RM)
Ground Floor	2,4766.08	1345.49	18
First Floor	2,0531.64	1345.49	15

Based on the calculation after being analysed, it can simply conclude that energy saving of Roxy Hotel Padungan is RM3.00 per square foot.

4.3 Maintenance Cost

The purpose of conducting maintenance is to implement the replacement of dead plant if there is any on the green wall. Other than that, they also maintain the irrigation system, timer check and testing it to make sure that irrigation frequency set to water the plant follow the schedule that has been set. They also remove all the weeds in order to make the plants grow healthily.

Table 7 shows that the cost estimation for each mobilisation of normal maintenance work is in the range of RM3,672.00 per visit. The maintenance is conducted four times in a year which the cost would be RM14,688 per year.

Table 7: Maintenance Cost

Maintenance Cost (RM)	Size of Green Wall (sqft)	Maintenance Cost per Square Foot (RM)
14,688.00	5381.96	2.70

Based on the calculation made, maintenance cost of the green wall per square foot is RM2.70 per year.

4.4 Comparing Between Maintenance Cost and Annual Energy Saving Using Cost Benefit Analysis

The third objective of this study is to compare the cost of maintenance on maintaining green wall and the annual energy saving of the green wall through cost benefit analysis. The final result shown in Table 8.

Table 8: Cost Benefit Analysis

Energy Saving (RM)	Maintenance Cost (RM)	Ratio
3.00	2.70	1:1.1

Overall, result shows that annual energy saving by green wall gives slightly benefits than the cost on maintaining the green wall.

5. CONCLUSION

This research has found the difference and knowledge regarding green wall. Even though green wall has been used for ages, but the amount of building that implementing green wall is still little. Besides, there are many benefits that can be provide by green wall and one of benefits that can be highlighted is energy saving. In order to maintain the green wall, the greenery system can be monetarised which has been calculated in this study. This research can be one of the references to the public to gain knowledge and spread awareness regarding green wall and green building.

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