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Assessing Components of Energy-Efficient Retrofitting at Heritage Buildings in Buffer Zone of Penang: Aiming for Net-Zero Energy Building Status

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ABSTRACT

Various components of successful energy efficient renovations in heritage buildings have been identified to create heritage buildings that aim to become Net Zero Energy Buildings (NZEB). Heritage buildings, with their historical and architectural significance, present unique challenges in achieving NZEB status while maintaining their integrity. Therefore, proactive steps must be taken to preserve historic buildings by implementing activities that can contribute to energy efficiency retrofitting at heritage buildings. The aim of this research was to assess the components of energy-efficient retrofitting at case study (heritage buildings) that can strike a balance between energy efficiency improvements and the preservation of the historical and architectural heritage buildings in the buffer zone, Penang. During assessment, there are five components that were assessed including ventilation, air conditioning, lighting, solar photovoltaic and smart control. This study makes full use of qualitative methods by integrating insights from observation and detailed case studies. As a result from assessment and observation, it was found that all buildings required to implement ventilation (case study 1), lighting (case study 1), solar photovoltaic (case study 2), smart control (case study 2) and air conditioning system (case study 3). As a proactive measure, early exposure should be given in relation to NZEB and should be applied to the community especially among students of higher education institutions so that they can care for and preserve historic buildings and the environment for the future generation and generate the national economy in various sectors.

1. Introduction

Heritage building retrofitting in Malaysia still is at infancy [1]. The term heritage building stands for significant and historical landmarks, but their energy-efficient designs and materials used represent a unique obstacle to for sustainability. The three factors that determine if a property is worthy to be list as heritage are historic significance, integrity and context. Furthermore, these buildings hold significant value in representing the past and contributing to the culture, heritage and society of a region, which is why they are protected and maintained. By implementing effective

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maintenance, preservation and protecting measures, it is possible to achieve Net Zero Energy Building (NZEB) designation for heritage buildings. Achieving NZEB status in these structures necessitates a careful balance between preserving their historical value and enhancing energy efficiency.

In addition, energy-efficient retrofitting is a fundamental component of the transition to NZEB in heritage buildings. A study by [2] investigated the significance of this modification. They suggest that insulation, window upgrades and heating, ventilation and air-conditioning (HVAC) system improvements are important to reduce energy consumption. There are few elements to achieve NZEB by using energy-efficient element including lighting such as natural lighting and artificial lighting [3]. However, the renovation of heritage buildings poses unique challenges compared to modern structures. Therefore, the selection must be done carefully, that is, using methods and technology that can be used to provide a useful and cost-effective environment [4]. Therefore, all parties must play an important role by educating the new generation with awareness of the concept of sustainability that can help the earth slow down the emission of greenhouse gases [5].

Retrofitting is a practice or reformation of an old building into new space to improve the performance of the building and retrofitting heritage building to energy efficiency building. Retrofitting in heritage buildings require innovative approaches to incorporate energy-efficient components without compromising originality and collaboration with new technologies to perform sustainability structure by reducing energy usage [6]. This requires matching the aesthetics, material and design of the original structure. Custom solutions and craftsmanship may be required to achieve this delicate balance. In addition, it also has the challenge of maintaining historical features. Historical and architectural significance make heritage buildings being highly valued. Retrofitting must balance energy-efficiency requirements with the preservation of original features without compromising the building's original appearance. Hence, to protect and enhance the heritage value of the structure, solutions should be adapted.

2. Methodology

This research paper used a qualitative approach to obtain data and information. The checklist has been previously developed, and that checklist has been used in conducting an observation at three selected case studies concentrating on the NZEB in heritage buildings for energy efficiency.

2.1 Observation and Case Study

Observation for this research aimed at three buildings by referring to heritage buildings depending on its type, function, age, conventional building and design with different functions and not recognized as green buildings. The selected case studies were at the Buffer Zone, Penang and is shown in Table 1.

Table 1
List of heritage buildings that were chosen as case studies

Description	Case study A	Case study B	Case study C
Building name	Segara Ninda Residence	Thean Onn Senior Home	Syed Al Attas Mansion
Location	5-29, Jln Penang, Georgetown, 10000 George Town, Penang.	152, Lebuh Carnarvon, George Town, 10100 George Town, Pulau Pinang	Lbh Armenian, George Town, 10450 George Town, Pulau Pinang
Building age	More than 150 years old	More than 150 years old	More than 150 years old
Function	Guest house	Senior citizen house	Two-storey mansion

3. Results and Discussion

3.1 To Assess the Components of Energy-efficient Retrofitting at Heritage Buildings that can Strike a Balance Improvement and the Preservation of the Historical and Architecture

3.1.1 Energy-efficient element at heritage building

Energy efficiency in heritage buildings involve the implementation of measures to reduce energy consumption while maintaining the historical and architectural integrity of the structure. This is to achieve NZEB at heritage buildings. Therefore, a checklist have been successfully formulated for energy-efficient elements. The formulated checklist has been used in assessment of the three selected case studies (Table 2).

Table 2
Energy-efficiency elements at heritage building

Elements	Checklist	Building A	Building B	Building C
Ventilation	Fans equipped with variable speed controls	Yes	Yes	Yes
	Automated controls or sensor	No	No	No
	High-efficient filters in the ventilation system	No	No	No
	Incorporate natural ventilation strategies into the building	Yes	Yes	Yes
	Ventilation system integrated into building systems such as building automation system (BAS)	No	No	No
Air-Conditioning	System include variable speed compressors or fans to adjust output based on cooling needs	Yes	Yes	No
	System can operate at lower speeds during periods of reduced demand thus saving energy	Yes	Yes	No
	Automated sensors and control	No	No	No
	Set up controls to maintain comfortable temperatures while minimizing energy consumption	Yes	Yes	No
	Appropriately sized for air conditioning system	Yes	Yes	No
Lighting	LED lighting to reduce energy consumption	Yes	No	No
	Utilize natural light	Yes	Yes	Yes
	Schedule for turning off non- essential lighting during lower of occupancy	No	No	No
	Occupancy monitoring features to track occupancy levels	No	No	No
Solar photovoltaic	High-efficiency solar panels	No	No	No
	Appropriately size of photovoltaic system	No	No	No
Smart control	All building systems integrated into the smart control system	No	No	No
	Provided real-time monitoring	No	No	No
	Occupancy sensors or smart devices	No	No	No
	Remote access	No	No	No

3.1.2 Energy-efficient elements to be installed at heritage building

Based on the checklist from Table 2 above, energy-efficient elements to be installed at heritage buildings have been identified. This checklist details recommended technologies and practices to achieve energy-efficiency and heritage building preservation goals. This method can identify and prioritize elements that can be installed in heritage buildings to minimize energy consumption while respecting the unique characteristics and constraints of heritage structures.

3.1.2.1 Case study A

Based on the first case study carried out at Case study A, the component of energy-efficiency elements that can be implemented to balance between increasing energy efficiency and preserving the historical and architectural importance of heritage structures that is shown in Table 3 is to apply ventilation elements. Ventilation is also considered as one of the sustainability elements. Ventilation is a system that moves air from outdoor to indoor spaces to provide healthy air for occupants yet increase thermal comfort to occupants. For example, thermal buoyancy and air currents are the methods to ventilate indoor and outdoor air through building envelope openings and windows, doors, chimneys and so on [7]. The different temperatures between the inside and outside of the building also affect the thermal buoyancy system to maintain proper ventilation in the building [8]. Next, this method was to improve indoor air quality and thermal comfort while respecting the building's historical integrity. For example, the use of natural ventilation using existing architectural features such as operable windows to maximize natural airflow within the building and help control humidity.

Lighting can be considered as one of the sustainability elements as it is the core of the performance of a building, the building will not be functioned without light, therefore implementing components of energy-efficiency such as lighting at heritage buildings was also highlighted in Table 3. In order to improve the performance of completing every task, sufficient and comfortable lighting should be provided to improve visibility to avoid the causes of distraction or discomfort [9]. Lighting can be classified as natural and artificial lightings, suitable to be applied at this building. Natural lighting is day lighting that is natural sources coming from the sun while artificial lighting can be categorized using technology to produce lights for occupants. Natural lighting is an energy-efficient element that is very suitable because it is a renewable material and it will not affect the environment [10]. The amount of natural light radiation into the building can be maximized with day lighting and reduced internal temperature, thus increasing the comfort of the occupants because it can reduce glare directly into the building. Day lighting is accessible through windows [10] and the use of natural lighting is also through reflected light [11].

Table 3
Energy-efficiency elements to be installed at heritage building

No.	Issues	Building A	Building B	Building C
1.	Providing adequate ventilation while minimizing energy loss through heat recovery systems and natural ventilation strategies	Yes	No	No
2.	Using energy-efficient air-conditioning to optimize indoor comfort and reduce energy consumption	No	No	Yes
3.	Use Light Emitting Diode (LED) bulbs and implement lighting controls to reduce electricity usage	Yes	Yes	No
4.	Install solar photovoltaic panels	No	Yes	No
5.	Implement occupancy sensors, and building automation systems to optimize energy usage	No	Yes	No

However, artificial lighting is also suitable for use in this building. For example, the use of LED because it is more efficient than other bulbs. Most consumers use LED bulbs because they can provide energy with less heat. It also has a longer life span as it can last for about 50,000 hours or more [12]. Therefore, LED lights are suggested to be used in case study A because it has a large interior space that is more suitable for installing LED lights in corridors, interior spaces and so on. This technology is also suitable to be applied in heritage buildings because the cost is cheaper compared to implementing energy-efficiency elements such as solar photovoltaic and so on.

3.1.2.2 Case study B

Next, a component of energy-efficient retrofitting that can achieve a balance between increasing energy-efficiency and preserving the historical and architectural significance of heritage structures in the second case study was through the use of solar photovoltaic systems as mention in Table 3. Solar energy requires lower maintenance and is applied as a common renewable energy source [13]. However, solar technologies such as photovoltaic panels have limited implementation in legacy contexts compared to mainstream infrastructure [14] for example, by installing solar photovoltaic panels on less visible roof areas or integrate them into existing features. It is important to integrate renewable energy generation while maintaining the historic integrity of the building. Solar photovoltaic captures the sun's rays and converts sunlight into electricity.

This system is suitable to be applied in this case study because the building has many rooms that accommodate nearly 80 seniors from low-income families. Thus, this step has the potential to become a cost-saving electricity producer and is very suitable because it can provide comfort to the population. In addition, solar photovoltaic systems are able to meet the specific energy needs of buildings and their users. This step is particularly suitable because it can integrate renewable solar energy.

Next the use of occupancy sensors in case study B can significantly optimize energy use while preserving the historical and architectural significance of the building. Occupancy sensors are devices that reduce energy consumption by only activating lighting if people are present. Occupancy sensors are intended to detect the presence or absence of people in a room or area. With this strategy, the sensor automatically turns on the lights when someone enters the space and turns off the lights after a user-designated time period if no movement is detected. Occupancy sensing systems work to, provide feedback to support occupant behavior changes, optimize building control systems as well as maximize document savings in relation to occupancy. In addition lighting, HVAC systems and other electrical devices can be controlled through the use of this technology. For example, occupancy sensor installation works to turn lights on or off automatically when occupants enter or leave the room. This reduces the waste of energy from lights left on in unoccupied spaces, this method is very proactive because most occupants living in this senior home house have certain problems such as being easily forgetful and causing them to ignore the electricity they use. Furthermore, a building automation system (BAS) is also an important step to control and monitor building services such as HVAC, lighting, security and more because it uses programmed sensors to automate operations and optimize energy efficiency.

3.1.2.3 Case study C

The third case study was the case study C. It was found that this building does not have air conditioning to provide cooling inside the building for the comfort of the building's visitors. Therefore, components of energy-efficient retrofitting that can achieve a balance between improving energy-efficiency and preserving the historical and architectural significance of heritage structures such as using air-conditioning in these buildings were encouraged because they can provide cooling without affecting the historical appearance of the structure. Spaces in the building that require air-conditioning must be identified first for the comfort of the occupants before installation. Furthermore, the use of air-conditioning that can maintain a stable humidity condition without using excessive energy was encouraged. Heritage buildings can achieve a balance between energy-efficiency improvements and preservation goals with this approach. This approach not only helps in reducing operational costs but also contributes to the long-term sustainability and cultural value of these architectural treasures.

4. Conclusions

In conclusion, the focus of the observation and case studies in heritage building to make sure heritage buildings can be aiming at a Net Zero Energy Building (NZEB) by assessing the component of energy-efficient retrofitting in their building and can be implemented in future Malaysian construction industry was achieved. It was necessary because of there exists issues in achieving NZEB such as the complexity of the historic buildings required retrofitting solutions which have a whole-building approach [15]. Therefore, this study has been conducted to assess the possible elements that can be implement at each heritage buildings (case study). From the findings, it was suggested that green technology construction methods as well as maximizing the use of energy-efficiency elements such as ventilation and air-conditioning, solar panels, lighting and smart control to preserve the environment as well as the lifespan and air quality of the building. Although this method has been used for a long time, most owners of heritage buildings do not apply this element of energy-efficient retrofitting to achieve NZEB in their buildings and thus this method was given less attention therefore the level of community awareness and education, especially the owners of heritage buildings, on the importance of green building in a heritage building was low. As a proactive measure, early exposure should be given in relation to NZEB and should be applied to the community especially among students of Higher Education Institutions so that they can care for and preserve historic buildings and the environment for the future generation and generate the national economy in various sectors.

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