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Establishing Effective Operation and Maintenance that Enhances the Energy Performance of Green Office Buildings in Malaysia

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Abstract

The increasing concern of global warming occurring at an exceptional rate has led to a massive shift in the construction industry. Subsequently, the development of green buildings is on the rise. Along with the emergence of green buildings, the evaluation of the sustainability of a project is a necessity to ensure that the building operates according to the best practices. Various studies have shown that some green buildings are underperforming compared to their initial designs. Some are even found to be performing even worse than the conventional buildings. In addition, the operation and maintenance (O&M) aspect is often neglected in the initial design stages, despite its significance on the life span, performance, and operational expenses of the building. Therefore, this research aims to study the implementation of O&M in relation to the energy performance level of green office buildings in Malaysia. To achieve the objectives of this research, a qualitative method is used whereby the data are obtained through literature review and interviews. Qualitative data are analysed to explain the influence of O&M aspects on energy performance. It is found that the green office buildings with better implementation of O&M, particularly on the maintenance strategy and building occupant behaviour, are likely to achieve the smaller operational energy performance gap. Therefore, various practices are suggested to enhance the energy efficiency of green building, such as appropriate selection and implementation of maintenance strategy, adoption of building automation system, impose of incentives for energy efficient practices, and occupant involvement in O&M.

Keywords: Building energy index, energy efficiency, green building index, green office buildings, operation and maintenance

1.0 INTRODUCTION

The increasing concern of global warming is revealed to be happening around ten times faster than the rate of average ice-age recovery (Gaffney & Steffen, 2017). It is one of the reasons for the massive shift from traditional buildings to green buildings, especially in developed countries. In the United Nation's 2030 Agenda for Sustainable Development, businesses and countries are encouraged to explore opportunities that merges social, economic, and, environmental sustainability through 17 wide-ranging Sustainable Development Goals (SDGs). The SDGs aim to decouple economic growth from poverty, inequality, and, climate change (World Green Building Council, n.d.). Thus, the emergence of green building, known as a sustainable or high-performance building, aims to preserve the environment through efficient use of energy, water, and, other resources. Simultaneously, it helps to enhance the quality of life and achieve sustainable development through the incorporation of various measures (USEPA, 2016).

Along with the development of green buildings, the evaluation of the project sustainability has become a necessity so that buildings are developed and operate according to the best practices. Hence, green building tools are introduced by various countries to assess the performance of green buildings (Aghili et al., 2016). In Malaysia, the Green Building Index (GBI) is a popular and recognised green rating tool that is specifically introduced for local social, infrastructure, and economic development (Singh, 2019). Aside from GBI, there are also other green building rating tools, such as GreenRE and other government-driven rating tools like PHJKR, MyCrest, Green PASS, etc. Generally, they target to optimise building performance and reduce associated environmental impact through the provision of measurement on the environmental effect of the building as well as a set standard to assess the building based on the nine primary themes of sustainability (Foo & Fuad, 2018).

Despite green buildings being known and certified as sustainable buildings, several studies have shown green buildings to be underperforming from the level predicted or designed during their operational stage (Wu et al., 2020). The actual performances of many green buildings were reported to be below expectation, whereby some were found to have performed worse than conventional buildings

(Geng et al., 2019). A research by Scofield (2013) also indicated that 25% of the green buildings failed to perform as well as designed from the 121 samples of LEED-certified buildings by comparing their actual and designed energy consumption.

The underperformance of green buildings is hypothesised to correlate with the operation and maintenance (O&M) of the buildings throughout its lifecycle (Bordass et al., 2001; Cheng et al., 2016; Zaid et al., 2017). Au-Yong et al. (2022a) highlighted that O&M of the buildings is crucial to retain the granted green certifications. An effective O&M can help a building achieve the intent of its original building design. However, according to Zainol et al. (2014), green buildings in Malaysia are said to have not performed optimally during the operational stage due to the Malaysian "green" development that mostly focuses on merely the design, material, construction, and building technology to acquire green certification. This resulted in the neglect of the O&M aspect in green buildings despite its significance on the life span, performance, and operational expenses of the building. Taking into cognisance of the arguments between the O&M and the energy performance of green buildings, a question on how does O&M influence the green building performance is raised. To address the question, this paper aims to examine the aspects of the O&M, and their relationships with the energy performance of green office buildings in Malaysia whereby effective O&M strategies are then recommended.

2.0 GREEN BUILDING

Green building is recommended to mitigate the negative impact of building and construction development on health and environment. It is resource-efficient and can ensure improvement of well-being and friendly environmental characteristics (Oluwunmi et al., 2019). Furthermore, green building development provides the triple bottom line benefits regarding sustainable development from the aspects of social performance, environmental performance, and economic performance (Zaid et al., 2017).

Socially, green building enhances the occupants' health and comfort, increases the aesthetic qualities, reduces the strain of local infrastructure, and improves the overall quality of life (USEPA, 2016). As for environmental performance, green building enhances and protects ecosystem and biodiversity, improves quality of water and air, as well as conserves and restores natural resources. Economically, it reduces operation costs, creates, expands, and shapes the market for green services and products, improves the productivity of occupants and optimises buildings' life cycle (USEPA, 2016).

Since this research targets to investigate the relationships between the O&M aspects and the energy performance of green office buildings, energy efficiency of the green office buildings is focused. The energy efficiency is one of the key elements to be measured in any green building rating tools such as the GBI.

2.1 Green Building Index (GBI)

Green buildings are mostly constructed and developed with reference to the guidelines of green rating systems that serve as the guidance for the "green" measurements (Adler et al., 2006). Hence, various green building rating systems are developed and established in the attempt to incorporate the concept of "total quality". In Malaysia, GBI is a popular green rating tool that has been widely used for the certification and evaluation of green buildings. The launching of GBI in 2009 has brought about an increase in awareness of green buildings among all stakeholders (Pandey, 2016).

GBI evaluates the performance of buildings and their environmental design based on six main criteria, namely sustainable site planning and management, energy efficiency, water efficiency, material and resources, indoor environmental quality, and innovation. Points are allocated for each criterion, whereby the certified green buildings under GBI will then be classified into different categories, such as platinum, gold, silver, and certified according to the total amount of points achieved on a 100-point scale (GSB, 2011).

In order to achieve the paper aim, this research only emphasises on the criterion of energy efficiency, particularly on the Building Energy Intensity (BEI).

2.1.1 Energy Efficiency

Energy efficiency (EE) is the key to achieving sustainability in green building developments and through which the reduction of energy consumption in the construction industry is becoming more significant for many organisations (Chen & Abualrejal, 2015). USGBC (2014) defined EE as consuming less energy to complete the same amount of task whereby energy waste is eliminated. Thus, EE is emphasised as a priority in the GBI assessment. It holds the most weightage among the six criteria with a maximum of 38 points out of a total of 100 points allocated to it (GSB, 2011).

Nonetheless, Zaid et al. (2017) mentioned that GBI is still lacking in terms of its strategies on energy management compared to its South-East Asian counterparts, such as BERDE Philippines and Green Mark Singapore. The incapability of the GBI tool to manage energy during a green building's operational stage hence resulted in the substantial consumption of energy for GBI-rated green office buildings in Malaysia (Azizi et al., 2012).

2.1.2 Building Energy Intensity (BEI)

BEI is a benchmarking tool used to monitor the energy performance of a building by indicating the energy intensity used per meter square area of the building. It is calculated by taking the ratio of the annual energy consumption of a building (kWh/year) and the net floor area of the building (NFA) as shown in the formula below (Suruhanjaya Tenaga, 2019):

$$\text{BEI (kWh/}m^2\text{/year)} = \frac{\text{Annual Energy Consumption (kWh)}}{\text{NFA (m}^2\text{)}}$$

BEI is an important assessment measurement in GBI for the energy efficiency category. The energy efficiency performance obtains higher points when the BEI value is lower. Therefore, green office buildings are considered to be energy efficient if their BEI does not exceed the baseline of 150 kWh/year as determined by the GBI assessment (GSB, 2011).

3.0 O&M ASPECTS THAT AFFECTING ENERGY PERFORMANCE OF GREEN BUILDINGS

According to British Standard BS 3811:1984, maintenance is defined as *"the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function"* (British Standards Institution, 1984, p. 1). Building maintenance encompasses a building operation where it is necessary to operate, maintain and manage the building. Hence, the term O&M is a combination of both building operation and building maintenance.

An effective O&M enables a building to achieve its original building design intent whereby it is also the discipline through which long term goals of energy efficiency, water efficiency, resource conservation, economy, etc. can be reached while fulfilling the health, safety, and comfort requirements of the occupants (Bobenhausen, 2016). Thus, a few aspects of O&M may directly or indirectly affect the energy performance of green buildings, including the follows.

3.1 Faulty Design

O&M is often neglected during the design and construction stage as architects and contractors tend to focus more on the green building technology, building materials, design, etc. instead of the maintainability of the green building (Mohammad et al., 2014). As a result, the effort to maintain and solve the defects caused by faulty design after the completion of the building may implicate higher O&M cost (Al-Hammad et al., 1997).

The energy efficiency of green buildings is influenced by the building design. For instance, it is crucial to focus on the accurate estimated of spaces during the design phase and how they will be used during the O&M stage to reduce the differences between the predicted and actual energy consumption levels (Lin et al., 2018). The selection of building envelope also plays an important role in the energy consumption of green buildings, such as the installation of windows with higher thermal characteristics that providing better insulation, minimising heat transfer and hence, reducing strain on the air-conditioning system.

3.2 Project Management

Good relationship and communication between designers and the maintenance team are vital at the design stage. The inputs offered by the maintenance team can greatly improve the green building's life-cycle performance in considerations of constructability, maintainability, operability, and serviceability (Meng, 2013). Likewise, project managers should communicate with energy managers to understand and ensure the energy efficiency of the building.

Problems that may occur in a project like incomplete construction documents, specifications, and plans can cause misinterpretation of project plan. Then, time limitation in constructing a green building can also affect the quality and performance of the building since the building encompasses a more complex system and technology (Mohammad et al., 2014).

3.3 O&M Management

Maintenance management aims to enhance the planning, implementation, use of appropriate tools and materials to reduce the total life cycle cost and the need for repair of building defects (Horner et al., 1997). Thus, proper planning of the maintenance policy, maintenance practices, and maintenance strategies are important as it will ultimately affect the performance of the green building.

3.3.1 Maintenance Policy with Energy-Efficient Consideration

A relevant maintenance policy is significant to optimise the energy performance of green buildings. It provides the maintenance management a framework to ensure that the facilities are effectively maintained while supporting the strategic objectives of O&M (Zawawi et al., 2016). A clear policy regarding energy efficiency is important as it provides a defined division of responsibilities for O&M. and must Meantime, it must be periodically updated and assessed.

According to Ding and Kamaruddin (2015), maintenance policy nowadays is more related to the maintenance optimisation model whereby it is classified into preventive, corrective, predictive, design out, and autonomous maintenance. However, maintenance policy that has energy efficient consideration is not commonly found (Firdaus et al., 2019).

3.3.2 Maintenance Strategy

From the maintenance policy, effective O&M strategies to ensure and enhance the energy performance of green buildings are then decided and implemented. As such, maintenance strategies are adopted to extend the lifespan of buildings and the installed services. Typically, maintenance strategies are categorised into planned maintenance and unplanned maintenance as in BS 3811:1984. In relation to

maintenance of green building, Au-Yong et al. (2022b) recommended the application of total productive maintenance (TPM) as an effective strategy in the O&M of green office buildings. The strategy involves all employees in the O&M in order to achieve the energy efficiency of the buildings.

3.3.3 Periodic Energy Audit

Periodic energy audit is a form of monitoring the energy efficiency of green building by detecting and identifying any possible defects and failures. It is an inspection that helps to reduce downtime of the equipment that subjects to random failure (Mathew, 2008). Similarly, housekeeping is an energy saving practice implemented at a low cost or at no cost, which enables the auditor to identify wasted energy by performing visual inspection during a walk-through energy audit. Hence, housekeeping is mostly incorporated into an effective energy management programme nowadays (Firdaus et al., 2019).

3.4 Resource Management

Maintenance resources include people, equipment, and materials that are utilised in ensuring the performance of green buildings. A research by Darko et al. (2017) argued that the shortage of skilled workers, lack of sufficient knowledge regarding tools for the green building management process, and higher project costs are some of the many causes that contributing to the poor performance of green building. Therefore, O&M personnel are the front liners who responsible for operating the building. Thus, the energy efficiency of the building is greatly dependent on the personnel's knowledge, skills, and attitude (Yik et al., 2002).

3.5 Maintenance Budget

Inadequate maintenance budget will lead to unavailable of maintenance implementation and then implicate building failure, despite the building maintenance being specified and planned correctly (Flores-Colen & de Brito, 2010). The issue may lead to additional maintenance expenditure due to the postponement of planned maintenance activities (Mohammad et al., 2014). As such, the budget allocation for O&M of green buildings is essential as it will affect the decision making of the maintenance management such as the policy, strategies, hiring of human resources, etc.

The inadequate allocation of budget is linked with the failure of maintenance execution at the right time. As the maintenance works are being deferred, the defects and performance of the green building will continue to deteriorate and in return, they may require additional contingency cost for the remedial actions. In short, the maintenance budget will affect all O&M of green features including the energy performance of the green building.

3.6 Building Occupant Behaviour

The maintenance team might not able to detect certain defects promptly due to other task commitments. On this occasion, the feedbacks from the users become crucial. Prompt response to building failure is necessary to maintain the building performance and to reduce the maintenance cost. Nevertheless, this can only happen if there is no delay or failure in reporting the defects/problems by users (El-Haram & Horner, 2002). O&M effectiveness is dependent on the green building users, including the awareness towards defect occurrence in the systems that consume energy, and the initiative to report the defects via helpdesk etc.

Besides, building occupants play a significant role in the total energy consumption through their interaction with the building and its systems in adjusting to the indoor air quality and thermal comfort (Harputlugil & de Wilde, 2021). For instance, they are responsible for the energy consumption, emission, and waste produced through their actions of maximising their comfort by using the air-conditioning systems, lighting systems, plug loads and appliances, etc. Therefore, occupant behaviour is one of the important reasons for the performance gap in energy efficiency due to its complexity and dynamics that is hard to capture (Park & Nagy, 2018). Consequently, adequate awareness and training should be conducted by O&M management through O&M manuals, etc. to allow occupants understanding the effect of their behaviour towards the consumption of energy.

Taking into cognisance the possible influence of the O&M aspects towards the energy performance of green building, a conceptual framework is developed for this research as shown in Figure 1.

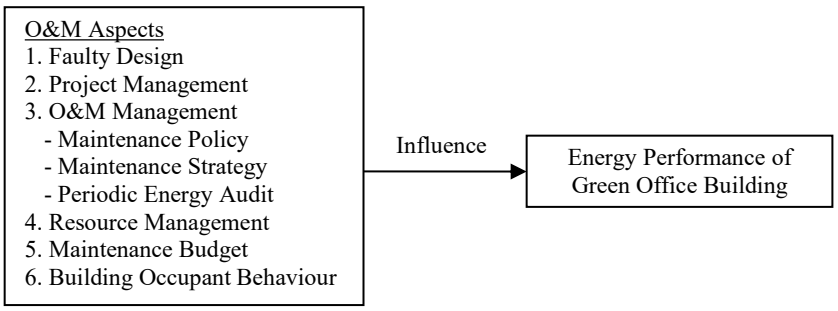

Figure 1 O&M aspects that influencing energy performance of green office building

4.0 RESEARCH METHODOLOGY

Leech and Onwuegbuzie (2009) described qualitative research as a method that tends to be expressed through words, to enable the understanding of concepts, experiences, thoughts and to gather more in-depth insights regarding the topic. This research method is commonly used to understand experiences, whereby it is more flexible and focuses on retaining the rich meaning during data interpretation. Thus, this paper adopted the qualitative research approach.

Table 1 Summary of O&M aspects from literature

O&M Aspects	References from extant literature
Faulty Design	Mohammad et al. (2014); Seeley (1987); Al-Hammad et al. (1997); Lin et al. (2018)
Project Management	Meng (2013); Mohammad et al. (2014)
O&M Management - Maintenance Policy with Energy Efficient Consideration - Maintenance Strategy - Periodic Energy Audit	 Ding and Kamaruddin (2015); Zawawi et al. (2016); Firdaus et al. (2019) Seeley (1987); Sagnier (2018); Au-Yong et al. (2022b) Mathew (2008); Firdaus et al. (2019)
Resource Management	Darko et al. (2017); Yik et al. (2002)
Maintenance Budget	Flores-Colen and de Brito (2010); Mohammad et al. (2014)
Building Occupant Behaviour	El-Haram and Horner (2002); Harputlugil and de Wilde (2021); Park and Nagy (2018)

The research began with literature review to determine the aspects of O&M that affecting the energy performance of green office buildings as shown in Table 1. Thereafter, the qualitative data was collected and analysed by following the process shown in Figure 2. Interviews were conducted with experienced personnel for further insight regarding the relationship between these aspects and the energy efficiency of the building, as well as their recommendations for strategic O&M to enhance the energy performance. The qualitative phase concluded with analysis, and then segregated into conceptual themes which would be discussed in the findings.

Figure 2 Process of collecting and analysing the qualitative data

4.1 Interview

To examine the relationship between the O&M factors and the energy efficiency of green office buildings, experienced personnel from the industry were interviewed. Interview was a relatively efficient and concentrated method of collecting the information required to meet the aim of this research. As a first step, various GBI certified green office buildings were approached to identify potential interviewees who met the interviewee requirements. The interviewee requirements included personnel who had experience in managing the green office building and had at least 5 years of experience in O&M sector. After several consultations, a total of 5 personnel from different green office buildings, each rated with a different GBI rating, agreed to participate in the interview as stated in Table 2.

Table 2 Background information of interview participants and managed buildings

Participant	Job scope	Experienced in O&M field	GBI rating of managed building	BEI of managed building
Interviewee A	Green Building Certification and Energy Audit Consultant	Yes	Certified	135
Interviewee B	Property Manager	Yes	Certified	129
Interviewee C	Building Surveyor and Facility Manager	Yes	Platinum	60
Interviewee D	Facility Manager	Yes	Platinum	58
Interviewee E	Senior Executive	Yes	Silver	85

4.2 Content Analysis of Interview

Krippendorff, as cited by Amos et al. (2021), defined content analysis as a research technique for making replicable and valid inferences from data to their context. In this research, the content analysis was conducted by coding the collected data, separating the data into different themes (according to the O&M aspects), and writing up the findings to tie up with the literature. The analysis was focused to understand the relationships between the O&M aspects and the energy performance of the green office buildings, as well as to review the possible O&M strategies that enhancing the energy efficiency. The interviews were audio-recorded and transcribed to generate the most accurate themes which represented the interviewee's opinions. Although there were drawbacks to qualitative interviews, nonetheless, the intuitive sense of agreement among the interviewees on most of the aspects gave a validation on the quality of information provided. Lastly, discussions and inferences were made along with the literature.

5.0 FINDINGS AND DISCUSSION

5.1 Differences between O&M of Green Buildings and Conventional Buildings

Prior interpreting the relationships between the O&M aspects and energy performance, the comparison of O&M in green buildings and conventional buildings are discussed. All interviewees agreed that there are differences between the O&M of green buildings and conventional buildings. In green buildings, various considerations are to be accounted since there are multiple requirements and criteria to be complied with. Interviewee A (personal communication, March 31, 2021) stated that a typical O&M team normally only contemplates measures to make the building cost-effective. Contrarily, the O&M team of green office buildings needs to consider measures of enhancing energy efficiency, water efficiency, waste management, etc. instead of only focusing on the cost.

Interviewee C (personal communication, April 13, 2021) added that green buildings use systems that are more advanced as compared to conventional buildings, such as the installation of photovoltaic solar panels, automation systems, etc. to ensure they fulfil the assessment criteria. Thus, the maintenance cost, maintenance works, and the equipment used are different from the conventional buildings. This is the reason why the skill and knowledge of maintenance personnel towards the maintenance of green buildings are critical (Darko et at., 2017).

5.2 Relationship between O&M Aspects and Energy Performance

5.2.1 Faulty Design

Faulty designs as a result of the O&M not being taken into consideration during the design stage are a common occurrence (Interviewee E, personal communication, April 21, 2021). They then negatively affect the energy efficiency of the buildings. Designers are usually not involved during the operation stage of the building. Hence, issues such as accessibility, equipment installed, materials used, etc. that are not properly communicated beforehand with the O&M team result in challenges for the maintenance works. For instance, the ducting design is not optimum whereby certain parts restrict the airflow or there is no accessibility to equipment which adds to the maintenance budget.

Interviewee B (personal communication, April 7, 2021) mentioned that the selection of materials during the design stage is important. For example, choosing double glazing windows can help lower energy consumption by reducing solar heat transfer. He added that the clients often neglect the O&M considerations while providing inputs to the designers or architects in the design stage, as they are mostly not knowledgeable about the O&M of green buildings. Likewise, Interviewee A (personal communication, March 31, 2021) opined that faulty design occurs due to the lack of synchronisation between the clients' requirements and the design team.

Conversely, Interviewee C (personal communication, April 13, 2021) disagreed with the neglect of O&M considerations during the initial stage. Green buildings are required to submit an energy simulation during the design stage for the application of a green building certificate, whereby O&M aspects should have been considered. For GBI assessment, points are given for contract maintenance before building operation so the occurrence of faulty designs such as accessibility issues, etc. can be mitigated. Generally, all interviewees mentioned that O&M teams or specialists should be involved in the design stage to provide opinions and advice in ensuring effective and cost-efficient O&M during the operational stage.

Although it is true to a certain extent that O&M being neglected during the design stage (Mohammad et al., 2014; Zaid & Kiani, 2016), the stakeholders and professionals in the building industry are becoming more aware of the importance of O&M in a building life

cycle. It can be seen from the replies of interviewees that their O&M teams are often encouraged to be involved during the design stage of any renovation/construction projects. Besides the O&M team, third parties such as the specialists in specific fields are also consulted for a better understanding of the consequences and effects of a certain system designs or installations towards the energy performance, and possible improvement for building sustainability during operational stages.

5.2.2 Project Management

Overall, project management affects the O&M and energy performance of a green office building up to a certain degree. Interviewee A (personal communication, March 31, 2021) revealed that government buildings tend to have missing data that are not provided by the relevant authorities, resulting in various assumptions of data during the O&M stage. Interviewee B (personal communication, April 7, 2021) elaborated that project managers should at least have basic knowledge about green buildings and technologies or engage a green consultant for guidance. Modern technology has greatly increased the ease of communication and sharing of data between the parties. Nowadays, some useful software like Building Information Modelling (BIM) can help storing information that can then be easily tracked and referred during the O&M stage (Interviewee E, personal communication, April 21, 2021). For instance, it is crucial to continuously monitor the trend of BEI value of the green building, so that appropriate revision of O&M related policy can be done to optimise the BEI value.

The feedbacks are in-line with the literature review, whereby it is important to have good communication between the project management team and the O&M team to ensure the building's lifecycle performance (Meng, 2013). As mentioned by the interviewees, a construction project or refurbishment project involves various parties requires accurate data and information sharing to prevent any miscalculation or misinterpretation. that may result in the underperformance of the building. Nonetheless, modern technologies as suggested by the interviewees have greatly helped to occurrence of issues raised by Mohammad et al. (2014).

5.2.3 O&M Management

5.2.3.1 Maintenance Policy

Every building, including green office building, has certain guidelines to be complied. For example, the expected BEI value is included in the maintenance policy so proper measures can be implemented to meet the expectation. Thus, O&M guidelines are derived from the maintenance policy to ensure that the O&M works are carried out as required and specified. A data compilation period will be conducted for 2-3 years once the policies are implemented to ensure that it is beneficial and helpful (Interviewee A, personal communication, March 31, 2021). Likewise, Interviewee C (personal communication, April 13, 2021) stated that a standard form for Facility Management Contract is used to create a systematic guideline in his organisation. The policy contains the technical specification and performance requirement to ensure contractors performing as contracted. Energy efficiency are also taken into consideration too, whereby contractors are required to submit their programme for energy efficiency to the Facilities Maintenance Officer.

In summary, all interviewees agreed that maintenance policy is important as it sets out the goals, maintenance strategies for specific assets, the short-, mid-, and long-term plans. The policy enables building owners and their staff to have the same mind-set in achieving the goals and strategic objectives as supported by Zawawi et al. (2016). Contrarily, their statements oppose Firdaus et al. (2019), who argued that policies with energy efficiency consideration are not commonly found. According to Interviewee B (personal communication, April 7, 2021), green buildings that consistently renew their green building certifications need to constantly review their energy saving measures to maintain or improve the energy efficiency of the building. As such, the managed building has an Energy Policy and Management Improvement Plan that aims to reduce the level of energy consumption and BEI, implement the efficient use of natural resources, and thereby reduce the building's carbon footprint.

5.2.3.2 Maintenance Strategy

Interviewee E (personal communication, April 21, 2021) stated that the selection of maintenance strategies is based on the availability of budget as well as the priority and criticality of the assets. The correct selection and implementation of maintenance strategy can minimise the impact on energy performance. Interviewee D (personal communication, April 16, 2021) also responded that a suitable maintenance strategy can improve the management of manpower by identifying the type of skills and personnel to be allocated, the number of personnel required, etc.

Interviewee E (personal communication, April 21, 2021) further elaborated some examples of the implementation of maintenance strategies. Planned maintenance is implemented for Air Handling Unit (AHU) since it runs on variable speed drive where there is a set point for static pressure. Conversely, run-to-fail maintenance is implemented for the lighting system as light bulbs are only required to be replaced once they fail. As for scheduled maintenance, the manufacturer's recommendation interval for service tends to be followed. As the age of the asset increases however, the interval for maintenance needs to be reviewed and shorten since breakdowns may occur more frequently.

In a nutshell, there are various maintenance strategies that can be implemented as highlighted by Seeley (1987) and Sagnier (2018). However, the common maintenance strategies are found to be the scheduled maintenance, predictive maintenance, and run-to-fail maintenance. According to the interviewees, a suitable maintenance strategy is determined by the building condition and other circumstances. The right selection of maintenance strategies can ensure the operational efficiency of building services, reduce maintenance cost, and save energy as supported by Bordass et al. (2001).

5.2.3.3 Periodic Energy Audits

Periodic energy audit helps in saving energy consumption but not to a drastic extend, since the green building is initially intended to be energy efficient, or unless it is converted from a conventional building. Interviewee A (personal communication, March 31, 2021) mentioned that energy audits can increase the energy efficiency on average up to 15% and are usually conducted by third parties once every few years. Interviewee D (personal communication, April 16, 2021) stated that energy audits are essential as they help analysing whether the current maintenance strategies and energy saving measures are effective. Practically, GBI certified green buildings are required to undergo energy audits every 3 years for the verification of efficiency of all criteria before the GBI certification can be renewed.

Since the interviewees confirmed the practice of regular energy audit, the findings are in line with the recommendation of Mathew (2008) to have periodic inspection. Anyway, energy audit can be more beneficial if it is conducted more frequently. Unfortunately, the interviewees reasoned that energy audits are not conducted every year due to budget consideration. Additionally, it is recommended by Firdaus et al. (2019) to implement housekeeping through visual inspection during a walk-through energy audit. Nonetheless, the interviewees stated that housekeeping by the in-house team is now rarely done manually as EMS is incorporated to monitor the energy consumption, equipment, BEI, etc.

5.2.4 Resource Management

The interview findings showed that many building owners do not invest much in their in-house O&M team since sub-contractors, suppliers, and other relevant specialists must be constantly engaged for maintenance works. Interviewee B (personal communication, April 7, 2021) mentioned that although training programmes are given to the in-house staff, their skills and knowledge are not on par with the specialists. For example, the in-house staff may blindly agree to the third party's suggestion to replace certain parts of the AHU system to increase its efficiency while it can be solved by deep cleaning of the filters due to their inadequate knowledge of the system.

Interviewee C (personal communication, April 13, 2021) said that one of the reasons that affect the efficiency of the resource management is the familiarisation with the building. In his company, internal changes are made every 5 years for in-house teams, while the facilities management (FM) contract with contractors is re-tendered every 3 years. Hence, despite hiring knowledgeable and skilled personnel, the constant changing of teams for maintenance works may result incapability to fully comprehend the O&M of the green office building. It is also mentioned by Interviewee D (personal communication, April 16, 2021) that the energy performance of a building is related to the mind-set of personnel - unmotivated for self-improvement. He said that the skill level of O&M team is currently at a moderate level, but this needs to be improved as green technologies are advancing and they must be operated properly. Despite the company provides training programmes, it still depends on the staff themselves to take the initiative to learn and acquire new skills and knowledge.

It is suggested by Darko et al. (2017) that the shortage of skilled workers and lack of sufficient knowledge are some of the many causes that contribute to poor green building performance. Although it is agreed by interviewees that the skills and knowledge of in-house teams may not be on par with specialists, they argued that this issue can be overcome and will not significantly influence the building performance. Contrarily, Yik et al. (2002) emphasised that O&M personnel are responsible for the operation of the building, whereby the building's energy efficiency is greatly dependent on their knowledge, skills, and attitude. Nonetheless, some of the interviewees explained that it does not matter if the personnel are not extremely knowledgeable or skilful as they can always seek help and advice from the specialists.

5.2.5 Maintenance Budget

It is found that most building owners are quite supportive of the O&M works by allocating sufficient budget. Maintenance budgets are essential as it will determine the maintenance works to be carried out in the following year. According to Interviewee B (personal communication, April 7, 2021) and C (personal communication, April 13, 2021), the budget allocation depends on the planned maintenance activities of the systems and reference of budget in previous years. In case of unexpected breakdowns that are not within the maintenance plan, an extra or ad hoc budget is allocated without interrupting the budget allocated for the planned maintenance.

Practically, the zero based budgeting is commonly implemented (Interviewee E, personal communication, April 21, 2021). The budget is derived from zero and is determined through the identification of services and required works. During the process of budget determination, various compromises are made, where prioritisation and deferment of maintenance/replacement works are considered. In this occasion, the O&M team needs to be analytical and knowledgeable in order to justify the budget to the building owners.

The interview findings confirmed that inadequate allocation of the budget links to failure of maintenance execution at the right time causing maintenance works to be deferred, thus result in an additional cost for repair/replacement (Flores-Colen & de Brito, 2010; Mohammad et al., 2014). However, the interviewees highlighted that insufficient maintenance budget rarely occurs as building owners nowadays become more supportive on O&M matters. With adequate maintenance budget, the O&M activities can be executed accordingly without delay. Hence, the building and systems are likely to operate at the optimal state, including their energy efficiency.

5.2.6 Building Occupant Behaviour

All interviewees agreed that building occupant behaviour plays a role in the energy efficiency of green office buildings. As per Interviewee A (personal communication, March 31, 2021), occupant behaviour in government buildings is harder to manage as compared to private buildings due to the requirement of having to wear a formal working attire. Another example is the use of manual blinds for windows whereby some officers tend to leave the blinds closed during the daytime and switch on the lights instead, leading to the unnecessary

consumption of energy. Interviewee C (personal communication, April 13, 2021) also elaborated that the user's lack of knowledge regarding the building and its systems brings a negative impact to the energy performance. For example, the users tend to open the windows when they feel cold, leading to more energy consumption from the air-conditioning system. Cumulatively, the BEI is likely to increase and it affects the overall energy performance of the building.

In general, the interviewees mentioned that there is not much that can be done to change occupant behaviour except to educate and create awareness through relevant programmes, announcements, posters, and notices. Interviewee E (personal communication, April 21, 2021) further explained that human errors such as forgetting to switch off lights and plugs, etc. can be mitigated by installing automation systems like sensors.

In short, the results supported that building occupants play a significant role in total energy consumption through their interaction with the building and its systems (El-Haram & Horner, 2002; Harputlugil & de Wilde, 2021). Interviewee A also described that occupant behaviour is different from one to another and thus, showing the complexity and dynamics of building occupants that are hard to capture as highlighted by Park and Nagy (2018). Therefore, it is vital to provide training and awareness programmes to educate the occupants regarding the effect of their behaviour towards the energy performance of the building.

5.3 Recommendation for O&M Strategies to Enhance Energy Efficiency

Most of the interviewee mentioned that one of the methods to improve on the O&M is to focus on the maintenance strategy especially for systems which consume significant amount of energy. Interviewee B (personal communication, April 7, 2021) added that the maintenance team needs to be familiar with the building such as how the systems and equipment run, the building characteristics, occupancy, working hours, etc. in order to be able to recommend the best strategies for maintenance. Interviewee D (personal communication, April 16, 2021) mentioned that the maintenance strategies should be revised constantly based on the current maintenance needs.

Then, Interviewee E (personal communication, April 21, 2021) suggested implementing the use of automation system, as it can greatly help the O&M team to monitor, analyse data, and ease their job. For instance, a large amount of data needs to be collected and analysed to plan for condition-based and predictive maintenance. With the aid of artificial intelligence (AI) and automation system, data analytics can be done within a shorter period with higher accuracy. Interviewee A (personal communication, March 31, 2021) also highlighted that auto-cleaning condensers for the air-conditioning system can be installed so that it is self-cleaning instead of having to carry out manual cleaning every 6 months.

Furthermore, Interviewee B (personal communication, April 7, 2021) stated that the government should consider providing incentives such as tax exemption, etc. for green buildings that manage to achieve an outstanding level of BEI. Although there are green building incentive plans being implemented by the government, the incentive criteria may not be applicable for all green buildings. Therefore, a more flexible incentive that is given to assist the operational phases of green buildings can help motivating stakeholders, top management, and O&M team to further improve the energy efficiency of the building. Similarly, Interviewee C (personal communication, April 13, 2021) mentioned that although photovoltaic solar panels are used, nonetheless, no rebates are given on this action. Thus, he suggested that rebates should be given for using renewable energy.

Lastly, most of the interviewees suggested the need to involve the building occupant in O&M. They opined that to ensure the building and systems are well maintained and operates at the optimal state, certain extend of O&M responsibilities can be borne by the occupants. Hence, various actions are recommended to promote the involvement of the building occupants in O&M, such as organising awareness programme, imposing penalty towards occupant who violate the energy saving policy, and encouraging the reporting of any detected abnormal conditions to the maintenance team. This suggestion is in line with the idea of Au-Yong et al. (2022b), promoting the application TPM that involves the employees in O&M activities.

6.0 CONCLUSION

In Malaysia, there is yet much evidence or studies to prove that green buildings are indeed performing as expected to their intended design and functions. Nonetheless, this research has shown that stakeholders are supportive and aware of the importance of investing in efficient O&M works. A well-structured and systematic implementation of O&M will result in better management of the building energy performance. The green office buildings with better implementation of O&M, particularly on the maintenance strategy and building occupant behaviour, are likely to achieve the smaller operational energy performance gap. Therefore, various practices are suggested to enhance the energy efficiency of green building, such as appropriate selection and implementation of maintenance strategy, adoption of building automation system, impose of incentives for energy efficient practices, and occupant involvement in O&M. Due to the COVID-19 pandemic however, the research data is limited only. Anyway, the research outcomes are still valid to provide a generic idea on how the implementation of O&M can influence the energy efficiency of the building. Furthermore, the paper recommends the future studies on similar conceptual framework to be conducted in mixed-method approach, including questionnaire survey and field observation. Thereby, the research outcomes can be generalised to the green building sector.

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