International Journal of Advanced Research in Technology and Innovation
e-ISSN: 2682-8324 | Vol. 3, No. 3, 35-48, 2021
http://myjms.mohe.gov.my/index.php/ijarti

Overview on the Implementation of Green Building Design in Malaysia, Singapore, Vietnam and Thailand

Nurul Noraziemah Mohd Pauzi[1*], Peck Kah Yeow[1], Zhu Hang Go[1], Tony Hadibarata[1]

[1] Faculty of Engineering and Science, Curtin University Malaysia, CDT 250, Miri, Malaysia

*Corresponding Author: nurul.noraziemah@curtin.edu.my

Accepted: 15 August 2021 | Published: 1 September 2021

Abstract: *In light of concerns relating to climate change and environmental pollution due to the overexploitation of resources and unsustainable development, the green building concept had been extensively carried out since 1960 to reverse the negative impacts of the development. The green building concept has been recognized nowadays and achieved tremendous development in benefits the environment. This paper therefore provides a summary of the principles, strategies, and challenges in the implementation of green building concept, and also highlighted the well-known green buildings in ASEAN countries. The findings of literature review can be summarized as follows: 1) Malaysia, Singapore, Vietnam, and Thailand are on performing well in the implementation of green building in development; 2) Some countries in ASEAN (i.e. Indonesia, Vietnam, Cambodia, Laos, and Myanmar) still fall behind in the implementation of green building is that due to the lack of governmental support and inadequate details of green building rating system; 3) The rating system used for rating green building in each country varies, but majorly adopting the US Leadership in Energy and Environmental Design (LEED) rating systems; 4) The implementation of green building concept does not only help in improving the environmental quality but also helping the company to save cost on the operation stage. This paper suggested that to further promote green building concept and increase its implementation, the government should provide more incentives to encourage organizations to adopt green building design in the construction industry. This review concludes that green building concept is a promising approach towards sustainable construction.*

Keywords: green building, design, energy consumption

1. Introduction

Building sector is significantly responsible for the high energy consumption, which the development of this sector will subsequently need even higher energy in the future (Azis, 2021). The rise in oil prices in the 1970s prompted substantial research and development to enhance efficient energy production and discover sustainable energy alternatives. Along with the environmental movement in the 1960s and 1970s, the first exploration in modern sustainable building was started (Ade & Rehm, 2020). International Energy Agency (IEA) and US Energy Information Administration (EIA) identified that construction and development are responsible for nearly half of the total energy consumption in the world, also showing that greenhouse gases from the buildings are substantial. Furthermore, IEA forecasts that buildings will continue to be the most critical energy-use industry by 2050, with more than 40% rise in global energy usage if measures on energy-efficient constructions are not taken (Lin et al., 2021) (Matisoff et al., 2016) (Oh et al., 2019). However, the energy consumption of the construction works for a conventional building is not considerably high compared to the building operation usages such as for the lighting, heating, cooking, ventilating, and cooling of the building. Siew et al. (Siew et al., 2011) claimed that the operation of a building is the major contributor to environmental problems. The construction phase only utilizes approximately 20% of the total electricity usage while the other 80% goes to the operation of buildings most of the time. In addition to the average 5% growth in the construction industry worldwide each year, energy production, waste disposal and the surrounding environment in the construction sector are of immense influence. Besides that, the conventional building is not only accountable for the release of harmful air pollutants, but also massive amounts of construction and demolition (C&D) waste which pose severe impacts on the wildlife and plants (Ortiz et al., 2009) (Geng et al., 2019) (Siew et al., 2011).

In this regard, the focus of future construction development is on green building design. Green building is a concept that combines a diverse range of ideas and guiding principles, claiming to lower or eliminate adverse effects on our climate and natural environment. It is an outcome of the development model which promotes on the efficient utilization of resources and enhances the quality of facilities (Kurdve et al., 2018) (Matisoff et al., 2016). Moreover, green building is indicated as sustainable or high-performance construction that builds structures through procedures that are environmentally conscious and energy-efficient across the life cycle of a building from implementation to installation, construction, operation, maintenance, remodeling, and demolition. Nevertheless, each green building does not share the same characteristics or specifications due to the location. For instance, countries around the world have diversified features such as climate patterns, distinctive customs and traditions, varied construction techniques, age groups, economy, technology availability as well as a broad range of financial, societal, and ecological priorities (Matisoff et al., 2016) (Tong, 2017). The era of green building concept began in the late twentieth and early twenty-first century after the overwhelming success of the “Greening of the White House”. The program was planned to improve “energy efficiency and environmental performance of the White House complex by identifying opportunities to reduce waste, lower energy use, and make an appropriate use of renewable resources, all while improving the indoor air quality and building comfort.” It was claimed that this scheme was able to save above $150,000 annually on electricity, water, solid waste management, and landscaping expenditures. Ever since 1996, approximately $300,000 have been conserved each year due to the increasing implementation of “green” projects (Shelton, 2007).

The benefits of green building design have been recognized worldwide and until now, it has been greatly implemented, and thousands of buildings have been regarded as “green”. Also, since countries in the ASEAN region are well-endowed with renewable energy sources, thus it has a greater opportunity to move towards greener development (Lidula et al., 2007) (Mungkung et al., 2021). Moreover, extensive studies have also been carried out to intensity the concept of green building design for reducing energy usage, efficiently use natural resources, and ensure the occupants’ comfort. Therefore, this paper is structured to review the principles, strategies, and challenges in the implementation of green building concept, and also highlighted the well-known green buildings in ASEAN countries.

2. Principles and Strategies of Green Building

Figure 1 shows the principles and strategies of green building design. As shown in the figure, the fundamental principles of green building design are to fulfill and meet the following required criteria, which are reducing the use of non-renewable construction materials, preservation of water quality, productive indoor environmental quality, reducing energy consumption, and minimization the adverse impacts of building sectors on the environment.

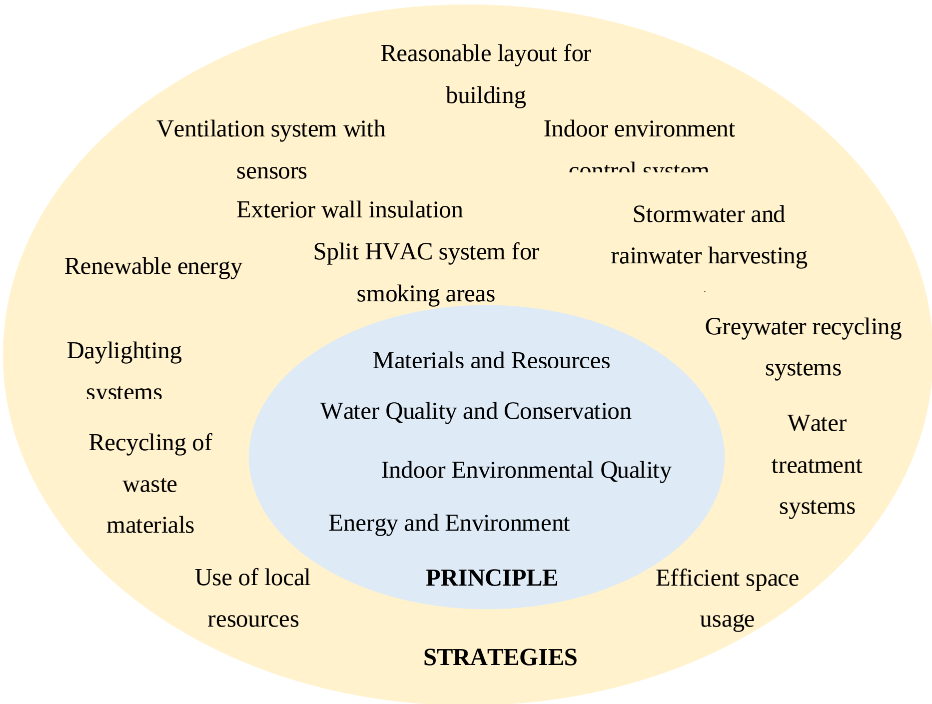

Figure 1: Principles and strategies of green building design

Materials and Resources

Non-renewable construction materials should be avoided and be replaced by efficient engineering design and utilization of waste materials. It is also recommended to prioritize materials that offer the least impact to the environment such as recycling content materials, efficiently utilizing modern engineered materials, and implement systems that prioritized the use of composite type materials. The best solution in designing a sustainable green building relies mainly on our human creativity and we can leverage our abundant labor force to make it happen (Umar et al., 2012) (Mohd Wira Mohd Shafiei et al., 2017). Therefore, we should not place our emphasis on solutions that only require the least amount of work. The use and optimization of modern engineered materials such as engineered composite materials insulated concrete materials and others should be prioritized as it is proven to offer greater strength and durability compared to conventional materials. Apart from that, high-recycled content materials can be implemented in the building structures which can even include but are not limited to fly ash, slag, and recycled concrete aggregate. Besides, it can also extend to consider refurbished office furniture, chairs with recycled parts (Thormark, 2006) (Khan et al., 2019) (Tong, 2020). Other than that, before all products and systems are implemented into the buildings, the end of their life should be evaluated to ensure that the materials can be reused and recycled accordingly. Therefore, it is preferred to have products and systems that able to be dismantled and recycled easily with minimal defects and contamination. Where practical, materials and systems that are utilized in the construction of the buildings must be readily obtained, locally manufactured, and also assembled to provide support to the designated regional economy. In turn, it will reduce the need for transportation and also provide the least impact on the environment (Hayles & Kooloos, 2008) (Samer, 2013) (Umar et al., 2012).

Water Quality and Conservation

The preservation of natural water cycle is needed to emulate a green and sustainable building. As a start, the attention should be shifted towards creating a close "replica" of the natural system by allowing retention of stormwater and allowed on-site infiltration. Apart from that, the recycling and reuse of rainwater, stormwater, and greywater should be highly emphasized whilst, reducing the use of unrequired potable water (Cheng, 2003) (Weinrich et al., 2012). The design of the building plays a vital role in creating an effective stormwater management system and also in promoting the existing natural flows of the land. Thus, it is required to be analyzed to obtain the most environmentally friendly and offering the least financial and time-consuming designs. In order to strategically and established a building, it is required to conduct a careful and thorough study to ensure the preservation of the key natural hydrological features (natural stormwater retention, recharge systems, and natural water infiltration) of the sites. It is also important to conserve existing mature vegetation as it plays a vital role in dispensing and also absorbing up to a limit of 30% of a site's rainwater through a process called evapotranspiration (Oindrila Das, Priyanka Bera, 2015) (Chang et al., 2011) (Azis, 2021). Due to the aid of low-impact stormwater technologies such as constructed wetlands, bio-retention, rain gardens, and permeable concrete paving, it has allowed water to seep through, promote groundwater recharge, and on-site retention. With that in mind, the water discharged from the site can be further processed either naturally or mechanically to be filtered from trash, oil, and other waste materials. In the phenomenon whereby the technologies are unable to be installed due to external factors, "hold and release" technologies such as dry retention ponds can be implemented (Chang et al., 2011). However, it does not provide as many benefits as the other technologies as it could not conserve the natural hydrological features of the site. Lastly, the design of the building should include low flow plumbing features and waterless urinals as it plays a role in reducing potable water. On-site water treatment systems can be utilized to filter rainwater, greywater, and also stormwater for toiletry and site irrigation uses (CEPT University, Ahmedabad, 2011) (Cheng, 2003) (Oindrila Das, Priyanka Bera, 2015).

Indoor Environmental Quality

A productive, clean, and healthy environment is also important for the building's occupants. Therefore, the building's design should encompass an optimal condition that is accessible and open to good air quality, ventilation, low noise pollution environment, and obtain sufficient daylight with natural airflow (Siew et al., 2011) (Gou et al., 2012) (Tong, 2017). To provide natural airflow, the building should be well equipped with sufficient amounts of windows and natural ventilation. Ventilation systems should be strategically placed around the building to provide an efficient heating and cooling function throughout the whole building. Moreover, the ventilation system should also function as a filtration system, which provides fresh clean make-up air to all the occupants in the building by effectively removing indoor air contaminants. Control sensors can be equipped onto the ventilation systems so that the system would automatically respond to the abnormal conditions when indoor air conditions fall outside the optimum range (Gou et al., 2012) (Tong, 2017) (Mohd Wira Mohd Shafiei et al., 2017).

The indoor environment control system is one of the important features in green buildings to enhance the utilization of natural light, ventilation design, air treatment, and other integrated systems. With the proper application of an indoor environment control system, the energy consumption of buildings can be reduced scientifically and systematically. Ventilation systems and air conditioning play an important role in the integrated systems for indoor environment control due to ventilation systems and air conditioning used up more than 50% of a general building's total energy consumption (Gou et al., 2012) (Sun et al., 2018). Therefore, it is important to implement the ventilation system and air conditioning of the building to improve the energy efficiency as the ventilation system and air conditioning for green building can save up to 30% of the system energy efficiency (Lockwood, 2006). In order to minimize the energy consumption for the ventilation system and air conditioning, it is important to optimize the design of the system and the key factor is to enhance the automatic control of the ventilation system and air conditioning (Afroz et al., 2020) (Tong, 2017).

Other than that, if smoking is permitted in the building, the smoking areas have to be isolated from other non-smoking sections that can be achieved with dedicated HVAC systems operating at negative pressure. To avoid discomfort to the non-smokers, the smoking areas should be located in such a manner that, non-smokers do not need to pass through them when accessing primary locations in the building (Samer, 2013) (Wimala et al., 2016) (Ferrari & Beccali, 2017). Besides, during the construction stages, it is of importance to ensure that the site itself is free from any possible contamination. Clear and outlined procedures are needed to minimize and contain the spread of construction debris and dirt to nearby areas. To ensure the efficiency and integrity of sensitive equipment such as HVAC, special attention and care are needed. Therefore, the implementation of environmentally friendly and cost-efficient cleaning agents should be prioritized as compared to conventional agents as they release harmful residues and volatile organic compounds (VOCs). Apart from using those agents, ever-readily fresh natural outdoor air can be used to purge and remove any airborne hazardous gases or particulate contaminants during the cleaning stage. During the planning stage, building materials that offer the least impact to the environment with moderate cost savings should be prioritized (Gou et al., 2012) (Mohd Nordin et al., 2018) (CEPT University, Ahmedabad, 2011) (Xue et al., 2019).

Energy and Environment

The principle of green buildings that is vital to be met would be the minimization of the building's adverse impacts on the environment. As a response to the alarming energy issues and to protect the environment, the building should be designed carefully by optimizing the resources, and highly encouraging the use of energy conservation techniques (Afroz et al., 2020). As a benchmark, building performance should have the capabilities to surpass the minimum International Energy Code (IEC) compliance level with a minimum threshold of 30%. Thus, the implementation of renewable energy and other alternative low impacts of energy sources should be emphasized (Lee & Yik, 2002). The use of energy-efficient lights can be the first step towards achieving greater overall energy performance in general office areas. Direct-based lighting can be replaced with indirect ambient lightings as it could provide a more comfortable working environment through reduced glares and improvement of overall lighting systems. Furthermore, sensors and control systems can also be implemented so that electrical lightings located around the buildings can be switched off when sufficient daylight is present in working areas (Sun et al., 2018) (Wang & Yang, 2020). Apart from lights, heating, ventilation, and air conditioning units (HVAC) can be installed with automated speed and pump controls. This would result in up to 40% increase in savings in overall energy consumption. Likewise, refrigeration systems should not be equipped with hydrochlorofluorocarbons (HCFCs) and other equipment that utilize Halon-based refrigeration as it poses a threat towards ozone depletion. When possible, the design of the building that implements the abundance of natural ventilation, evaporative cooling, and absorption cooling should be emphasized to reduce the other sources of man-made energies (Dimoudi & Tompa, 2008) (Panwar et al., 2011) (Alwisy et al., 2018) (Lockwood, 2006).

Meanwhile, in countries with four seasons, it is highly recommended that external shading devices with optimized passive solar orientation in buildings are implemented, which can maximize natural solar lightings during the winter months. Besides that, significant energy savings throughout the year can also be achieved by utilizing high-performance low-E glazing.

This can be done by insulating the pane glazing in windows with low-E film suspension as these coatings can offer sufficiently high amounts of light transmittance with low solar gains during summer. Apart from that, multiple thermal breaks can be installed at window frames and sashes to further intensify the reduction of overall energy consumption (Dimoudi & Tompa, 2008) (Alwisy et al., 2019). Other than that, the insulation in building walls plays a huge importance in heat energy dissipation. Therefore, it is recommended to implement advanced envelope building systems which might consist of but are not limited to structural insulated panel systems (SIPS) and insulated concrete form systems (ICF's) which can be used in light infrastructures. The thermally "decoupled" systems can offer significantly greater energy performance compared to other conventional systems (Papadopoulos et al., 2002). Up to now, there are several strategies used for energy saving in green building to help in reducing the energy consumption of the building in both the construction and operation phase such as daylighting systems, renewable energy, exterior wall insulation, and carefully designed layout of the building.

Daylighting systems

Lighting and daylight systems are important features in a building as light is an essential resource for workers to work in a building. Without any daylight or lighting systems, workers will be forced to work in a dark environment. Artificial manmade lighting could use up to 30% of the total power consumption of the whole building (Tong, 2017). Besides, the heat produce by manmade lighting will increase the environmental temperature which requires more energy used in the cooling system to reduce the heat. Natural daylight illumination is one of the aspects of green building application to allow sunlight to reach into the building while reducing the need of using the manmade lighting system. Subsequently, the power consumption for light sources will be significantly reduced and lessen the environmental pollution created by daylight systems. Tong (2017) (Tong, 2017) reported that the productivity of natural daylight systems is 15% higher than manmade lighting systems. The natural daylighting system will create more dynamic and healthier environments compare to the manmade lighting system. The natural daylighting system can also change the color, vision, and intensity of light to create a more comfortable working environment to improve learning and work efficiency (Tong, 2017) (Sun et al., 2018).

Renewable energy in green building

Renewable energy is a source of sustainable, unlimited, and clean energy that will reduce environmental impacts and minimize the production of secondary waste (Panwar et al., 2011). Solar energy is the most common energy that is easily accessible and is available throughout the year in ASEAN region countries. The average annual sunshine hours in ASEAN countries are between 2000-2600 hours (Siala & Stich, 2016). The all-year-round sunshine availability and long annual sunshine hours are favorable conditions for the utilization and development of clean solar energy. Currently, the common techniques used in green residential buildings and also included in the green building development plan are solar water heaters, solar cells, and solar energy air conditioning. However, the biggest difficulties face by the use of solar energy technology are due to the low energy conversion rate. Thus, more research on the energy conversion efficiency is required to increase the efficiency to allow solar energy to be more widely use and can be adapted into more technology involving green building and not only limited to air conditioning, water heaters and solar cells (Azis, 2021) (Lidula et al., 2007) (Chen et al., 2015).

Exterior wall insulation

The external wall insulation system of a building can helps in minimizing the energy consumption of a building in both cold and hot weather by improving the thermal performance. The implementation of an external wall insulation system could maintain the temperature desired inside the building, which will help in reducing the workload for air conditioning and other cooling systems to cool down the temperature in hot weather and the workload of heater to increase the temperature in hot weather. Subsequently, the energy consumption of the building significantly decreased. External wall insulation systems should be widely promoted for building exterior walls and not only limited to large buildings but also households (Tong, 2020) (Tong, 2017).

Reasonable layout for building

The orientation and shape of the building have a significant impact on the energy consumption of the building. Reasonable building design should be based on the function, size, and area of the building where the perspective of aerodynamics and thermodynamics must be considered in the design. For instance, cinemas, sports venues, and other large buildings have a higher internal heat than external heat. Thus, a more conducive heat design should be applied to the larger body shape building. Meanwhile, for a residential building, the main factor would be the instability of the external load energy consumption. It is because the heat factors are different for large buildings and residential building, where the appropriate layout should be designed for each type of buildings to ensure the energy consumption would be at the lowest during the construction stage and operation stage (Lidula et al., 2007) (Minh Do & Sharma, 2011) (Chen et al., 2015).

3. Application of Green Building Design

Malaysia

Several iconic green buildings in Malaysia are rated based on the GBI rating system. Among all, the Tun Razak Exchange (TRX) is rated as the “Platinum Rating” which is the highest certification in the GBI system. The TRX is also the only building to be certified with “Platinum Rating” under the township category in Malaysia. The TRX has a size of 70 acres and provides services such as serviced residences, offices, Kuala Lumpur’s new Central Business District (CBD), and The Exchange Mall. Within the 70 acres size of the TRX, there is a 10 acres City Park at the center of the TRX with sports and play facilities, venue spaces, and also an open green space. In addition, TRX also provides facilities such as pedestrian-friendly infrastructure, proper wastewater management, cooling, and energy utilization (Dwaikat & Ali, 2018). Another creditable green building in Malaysia is the Energy Commission Diamond Building. The Diamond Building was designed to optimize in several environmental aspects such as environmental quality, water efficiency, energy efficiency and to operate at a capacity of 85kW/m2 where other typical buildings in Malaysia operate at an average capacity of 210kW/m2. The water efficiency for the Diamond Building is achieved through the harvesting of rainwater for the toilet flushing. The building is also equipped with efficient water fittings such as aerated faucets, waterless urinals, and dual-flush toilets which have contributed to a 65% reduction in the consumption of potable water. Besides, the wastewater resulted from washbasins will be used for irrigation purposes for wetlands and gardens that were built for the building’s outdoor environment. The landscaping of the building also acts as a system to reduce the temperatures by providing shading from foliage (Azis, 2021) (Siew et al., 2011).

Singapore

The numbers of green building in Singapore are rising in the past few years where the range of green buildings include commercial building, residential building and even buildings for education development's purpose. Nanyang Technological University is listed as one of the most eco-friendly campuses around the world which are equipped with technology to increase resource efficiency and to reduce energy and water usage. Other than for an aesthetic appeal looks, the high-performance glass façade and green roof will help in maintaining the ambient temperature low. In addition, the lights within the university are equipped with photocell and motion sensors which help to minimize energy wastage (Liu & Ren, 2020) (Siva et al., 2017). Other than Nanyang Technological University, Capita Green is also one of the famous green buildings in Singapore, which is located at the center of Tanjong Pagar business district. More than 50% of the exterior of the Capita Green building is covered with lush foliage to provide fresh air and keep the workers in the office to be in touch with nature. The façade boasts of the building is also installed with double-skin glass which will helps in reducing the solar heat gain for maintaining a cool environment within the building. The building is also installed with a rainwater harvesting system for irrigating the garden of the building and to reduce water consumption. The air conditioning of the building is channeled by the sky forest on the rooftop of the building which will constantly provide the building with cool and fresh air while reducing the energy consumption (Tan et al., 2013).

Thailand

The Rama IX Super Tower is ASEAN's tallest building to have been certified Platinum rating by LEED. The super tower is designed to be energy efficient and environmentally friendly. The exterior of the super tower is covered with insulated glass to minimize energy consumption due to heat transfer. The super tower also used a high-performance air-conditioning system to ensure the ambient temperature inside the tower is constant by using variable air volume. The super tower is also installed with a solar panel to generate energy for the building (Lohmeng et al., 2017). Another exemplary green building in Thailand is the Pearl Bangkok office building. The building features some technology to help in reducing energy consumption such as low-iron and low-E glass to minimize heat entering the building while allowing natural daylight to enter into the building. The lighting system will be installed with a daylight sensor and using the LED bulb to reduce the energy consumption compared to traditional fluorescent lamps. The building also features a chiller air-conditioning system which will help in reducing energy consumption while minimizing the amount of carbon dioxide released. In addition, a CO2 detector system is installed to creates fresh and cool air from CO2 which will supply up to 30% of the total building's air usage. The water recycling and treatment features of the tower will help in reducing the usage of water by an average of 4686 cubic meters every year, which is equivalent to 40% reduction compared to a normal building (Sangkakool et al., 2018).

Vietnam

Green building in Vietnam is still relatively falling behind when compared to other ASEAN countries such as Malaysia and Singapore. However, UN House is one of the famous green buildings among the locals where it was awarded Gold by LOTUS rating system. The building archives a third of energy reduction compared to similar buildings without any green features. The building features some of the green technology such as smart environmental controls and solar water heating. In addition, the UN House used solar energy to power some of the energy in the buildings (Nguyen & Gray, 2016). The President Place is also one of the well-known green building which achieves LEED gold rating for the office building. This building is equipped with a time-operated and sensors energy-efficient lighting system to minimize energy consumption when not in use. Low energy loss glass is also equipped to reduce solar heat gain while minimizing energy loss. A rooftop rice paddy is also designed to minimize the energy consumption of air conditioning as the design will allow the circulation of clean air within the building (Minh Do & Sharma, 2011).1

Indonesia

The green building in Indonesia is also relatively less compared with Singapore and Malaysia. The Ministry of Public Works building in Jakarta is considered to be one of the exemplary buildings that encouraged the developers to invest and adopt the green building concept. The Ministry of Public Works building is rated as Platinum under the GBCI rating system. The building consists of several features such as a ventilation system, insulation system, and temperature control system (Berawi et al., 2019). These features help to minimize energy consumption and to optimize energy efficiency. Alamanda Tower is also one of the green buildings in Indonesia. The building has achieved Platinum certification under the GREENSHIP rating system. The features of the building include adequate exposure to natural daylight, a ventilation system, and water treatment. These features have created a stimulating and fresh workplace atmosphere while enhancing the energy efficiency of the building (Wimala et al., 2016).

4. Challenges

Nowadays, the inclusion of green building concept in the construction industry achieving increasing recognition as a feasible alternative to satisfy the public demand for ecologically responsible and sustainable buildings. However, the implementation of green building developments may not be noticeable because of the challenges of high capital costs, additional work for approval and clearances, and lack of resources and skills, which limits the broader acceptance of green building technologies (Mohd Nordin et al., 2018). The perception that the green building concept requires high cost for the construction and design are the primary obstacles that have discouraged the adoption of green building technologies by both developers and consumers. The capital cost for sustainable energy is also a leading constraint to accept high-performance infrastructures that can conserve electricity as part of the component of green building. Besides that, construction materials for green buildings are generally more expensive than conventional materials (Hayles & Kooloos, 2008). Consequently, many developers would eventually restrain themselves to involve advanced sustainable technologies. Other than that, the factor that limits the adoption of green building concept is that the developers and architects must go through a rather lengthy phase when applying for permits and authorizations. Adding up this additional workload and the amount of legislation before any construction of green building could be possible justifications that hinder its implementation. Moreover, there are green building ranking schemes in use across the world and some differ in their approaches with different standards. As a result, the decision-making process on the most suitable certification and ranking system for the particular project would be difficult and time-consuming (He et al., 2018).

In addition, the fact that green technologies are continuously improved and changing, the gaps of skills and knowledge are also widened, particularly in the field of energy construction projects and policies (Sangkakool et al., 2018). Liyin and Hong (2006) reported that the greatest skill and resource deficiencies are identified in the areas of energy quality management for the HVAC system, ability in the use of analytical instruments to assess energy efficiency in architecture and construction works, as well as the builders' competence in passive designs (Liyin & Hong, 2006). Other challenging components and skillsets of green building concept include ventilation, temperature, and daylighting control. The primary cause of insufficiency of labor and resource gaps is that skill standards evolve as technology and strategy are adopted or modified, where past skill sets are no longer competent. Therefore, skill development poses an important role in promoting green building knowledge and awareness (Lockwood, 2006) (Sangkakool et al., 2018) (Hayles & Kooloos, 2008). Past studies recommend that the financial institutions should provide investment opportunities to the developers that planning to establish and adopt a green building concept. Their role is important as they can provide the necessary capital needed for eco-friendly technologies to be developed whilst also preserving the environment. In addition, public sectors and relevant government agencies also play a role in creating awareness by creating information campaigns on green building concepts. Apart from that, the government should provide attractive incentives to the developers that willing to invest in green technologies. This can act as a platform to overcome the lack of understanding of green building concepts and also emphasize the need to protect our environment (Aliagha et al., 2013) (Umar et al., 2012) (Fan & Wu, 2020).

5. Conclusion

This paper reviewed the concepts and application of green building design in ASEAN countries. The review concludes that the concepts of green buildings (i.e. use of non-renewable construction materials, preservation of water quality, productive indoor environmental quality, reducing energy consumption) can act as a guideline to future and existing buildings. However, several challenges need to be encountered such as high capital costs and lack of skills as it limits further progress of green buildings concept. In a nutshell, green building concept not only benefits the environment but also helps in saving the cost of the operation by reducing the energy used. Some of the ASEAN countries such as Malaysia, Singapore, Vietnam, and Thailand have already achieved a tremendous result in green building, meanwhile, countries like Indonesia, Vietnam, Cambodia, Laos, and Myanmar require more effort in implementing green building. The reasons that some countries in ASEAN still fall behind in the implementation of green building is that due to the lack of governmental support and inadequate details of green building rating system. Therefore, in order to further promote green building concept and increase its implementation, the government should provide more incentives to encourage organizations to adopt green building design in the construction industry.

References

Ade, R., & Rehm, M. (2020). The unwritten history of green building rating tools: a personal view from some of the 'founding fathers.' Building Research and Information, 48(1), 1–17. https://doi.org/10.1080/09613218.2019.1627179

Afroz, Z., Burak Gunay, H., & O'Brien, W. (2020). A review of data collection and analysis requirements for certified green buildings. Energy and Buildings, 226, 110367. https://doi.org/10.1016/j.enbuild.2020.110367

Aliagha, G. U., Hashim, M., Sanni, A. O., & Ali, K. N. (2013). Review of Green Building Demand Factors for Malaysia. Journal of Energy Technologies and Policy, 3(11), 471–478. http://www.iiste.org/Journals/index.php/JETP/article/view/8596

Alwisy, A., BuHamdan, S., & Gül, M. (2018). Criteria-based ranking of green building design factors according to leading rating systems. Energy and Buildings, 178, 347–359. https://doi.org/10.1016/j.enbuild.2018.08.043

Alwisy, A., BuHamdan, S., & Gül, M. (2019). Evidence-based ranking of green building design factors according to leading energy modelling tools. Sustainable Cities and Society, 47(March), 101491. https://doi.org/10.1016/j.scs.2019.101491

Azis, S. S. A. (2021). Improving present-day energy savings among green building sector in Malaysia using benefit transfer approach: Cooling and lighting loads. Renewable and Sustainable Energy Reviews, 137(March 2020), 110570. https://doi.org/10.1016/j.rser.2020.110570

Berawi, M. A., Miraj, P., Windrayani, R., & Berawi, A. R. B. (2019). Stakeholders' perspectives on green building rating: A case study in Indonesia. Heliyon, 5(3), e01328. https://doi.org/10.1016/j.heliyon.2019.e01328

CEPT University, Ahmedabad. (2011). Green building materials and their common use in everyday life. E - Courses: Environment and Sustainable Development , January, 3. https://doi.org/10.13140/RG.2.1.1635.4323

Chang, N. Bin, Rivera, B. J., & Wanielista, M. P. (2011). Optimal design for water conservation and energy savings using green roofs in a green building under mixed uncertainties. Journal of Cleaner Production, 19(11), 1180–1188. https://doi.org/10.1016/j.jclepro.2011.02.008

Chen, X., Yang, H., & Lu, L. (2015). A comprehensive review on passive design approaches in green building rating tools. Renewable and Sustainable Energy Reviews, 50, 1425–1436. https://doi.org/10.1016/j.rser.2015.06.003

Cheng, C. L. (2003). Evaluating water conservation measures for Green Building in Taiwan. Building and Environment, 38(2), 369–379. https://doi.org/10.1016/S0360-1323(02)00062-8

Dimoudi, A., & Tompa, C. (2008). Energy and environmental indicators related to construction of office buildings. Resources, Conservation and Recycling, 53(1–2), 86–95. https://doi.org/10.1016/j.resconrec.2008.09.008

Dwaikat, L. N., & Ali, K. N. (2018). The economic benefits of a green building – Evidence from Malaysia. Journal of Building Engineering, 18(April), 448–453. https://doi.org/10.1016/j.jobe.2018.04.017

Fan, K., & Wu, Z. (2020). Incentive mechanism design for promoting high-level green buildings. Building and Environment, 184(May), 107230. https://doi.org/10.1016/j.buildenv.2020.107230

Ferrari, S., & Beccali, M. (2017). Energy-environmental and cost assessment of a set of strategies for retrofitting a public building toward nearly zero-energy building target. Sustainable Cities and Society, 32, 226–234. https://doi.org/10.1016/j.scs.2017.03.010

Geng, Y., Ji, W., Wang, Z., Lin, B., & Zhu, Y. (2019). A review of operating performance in green buildings: Energy use, indoor environmental quality and occupant satisfaction. Energy and Buildings, 183, 500–514. https://doi.org/10.1016/j.enbuild.2018.11.017

Gou, Z., Lau, S. S. Y., & Zhang, Z. (2012). A comparison of indoor environmental satisfaction between two green buildings and a conventional building in China. Journal of Green Building, 7(2), 89–104. https://doi.org/10.3992/jgb.7.2.89

Hayles, C. S., & Kooloos, T. (2008). The challenges and opportunities for sustainable building practices. Construction in Developing Countries International Symposium, January, 9.

He, Y., Kvan, T., Liu, M., & Li, B. (2018). How green building rating systems affect designing green. Building and Environment, 133(November 2017), 19–31. https://doi.org/10.1016/j.buildenv.2018.02.007

Khan, S., Maheshwari, N., Aglave, G., & Arora, R. (2019). Experimental design of green concrete and assessing its suitability as a sustainable building material. Materials Today: Proceedings, 26, 1126–1130. https://doi.org/10.1016/j.matpr.2020.02.225

Kurdve, M., Hildenbrand, J., & Jönsson, C. (2018). Design for green lean building module production - Case study. Procedia Manufacturing, 25, 594–601. https://doi.org/10.1016/j.promfg.2018.06.096

Lee, W. L., & Yik, F. W. H. (2002). Regulatory and voluntary approaches for enhancing energy

efficiencies of buildings in Hong Kong. Applied Energy, 71(4), 251–274. https://doi.org/10.1016/S0306-2619(02)00014-4
Lidula, N. W. A., Mithulananthan, N., Ongsakul, W., Widjaya, C., & Henson, R. (2007). ASEAN towards clean and sustainable energy: Potentials, utilization and barriers. Renewable Energy, 32(9), 1441–1452. https://doi.org/10.1016/j.renene.2006.07.007
Lin, Y. H., Lin, M. Der, Tsai, K. T., Deng, M. J., & Ishii, H. (2021). Multi-objective optimization design of green building envelopes and air conditioning systems for energy conservation and CO2 emission reduction. Sustainable Cities and Society, 64(September 2020), 102555. https://doi.org/10.1016/j.scs.2020.102555
Liu, Q., & Ren, J. (2020). Research on the building energy efficiency design strategy of Chinese universities based on green performance analysis. Energy and Buildings, 224, 110242. https://doi.org/10.1016/j.enbuild.2020.110242
Liyin, S., & Hong, Y. (2006). Improving environmental performance by means of empowerment of contractors. Management of Environmental Quality: An International Journal, 17(3), 242–257. https://doi.org/10.1108/14777830610658674
Lockwood, C. (2006). Building the Green Way Building the Green. Harvard Business Review, 1–9.
Lohmeng, A., Sudasna, K., & Tondee, T. (2017). State of the Art of Green Building Standards and Certification System Development in Thailand. Energy Procedia, 138, 417–422. https://doi.org/10.1016/j.egypro.2017.10.188
Matisoff, D. C., Noonan, D. S., & Flowers, M. E. (2016). Policy monitor-green buildings: Economics and policies. Review of Environmental Economics and Policy, 10(2), 329–346. https://doi.org/10.1093/reep/rew009
Minh Do, T., & Sharma, D. (2011). Vietnam's energy sector: A review of current energy policies and strategies. Energy Policy, 39(10), 5770–5777. https://doi.org/10.1016/j.enpol.2011.08.010
Mohd Nordin, R., Halim, A. H. A., & Yunus, J. (2018). Challenges in the Implementation of Green Home Development in Malaysia: Perspective of Developers. IOP Conference Series: Materials Science and Engineering, 291(1), 0–6. https://doi.org/10.1088/1757-899X/291/1/012020
Mohd Wira Mohd Shafiei, Hooman Abadi, & Wan Nadzri Osman. (2017). The indicators of green buildings for Malaysian property development industry. International Journal of Applied Engineering Research, 12(10), 2182–2189.
Mungkung, R., Sorakon, K., Sitthikitpanya, S., & Gheewala, S. H. (2021). Analysis of Green Product Procurement and Ecolabels towards Sustainable Consumption and Production in Thailand. Sustainable Production and Consumption. https://doi.org/10.1016/j.spc.2021.03.024
Nguyen, H. T., & Gray, M. (2016). A review on green building in Vietnam. Procedia Engineering, 142, 314–321. https://doi.org/10.1016/j.proeng.2016.02.053
Oh, B. K., Glisic, B., Lee, S. H., Cho, T., & Park, H. S. (2019). Comprehensive investigation of embodied carbon emissions, costs, design parameters, and serviceability in optimum green construction of two-way slabs in buildings. Journal of Cleaner Production, 222(2019), 111–128. https://doi.org/10.1016/j.jclepro.2019.03.003
Oindrila Das, Priyanka Bera, S. M. (2015). Water Conservation Aspects of Green Buildings. International Journal of Research in Engineering and Technology, 04(25), 75–79. https://doi.org/10.15623/ijret.2015.0425012
Ortiz, O., Castells, F., & Sonnemann, G. (2009). Sustainability in the construction industry: A review of recent developments based on LCA. Construction and Building Materials, 23(1), 28–39. https://doi.org/10.1016/j.conbuildmat.2007.11.012
Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in

environmental protection: A review. Renewable and Sustainable Energy Reviews, 15(3), 1513–1524. https://doi.org/10.1016/j.rser.2010.11.037

Papadopoulos, A. M., Theodosiou, T. G., & Karatzas, K. D. (2002). Feasibility of energy saving renovation measures in urban buildings. Energy and Buildings, 34(5), 455–466. https://doi.org/10.1016/s0378-7788(01)00129-3

Samer, M. (2013). Towards the implementation of the Green Building concept in agricultural buildings: A literature review. Agricultural Engineering International: CIGR Journal, 15(2), 25–46.

Sangkakool, T., Techato, K., Zaman, R., & Brudermann, T. (2018). Prospects of green roofs in urban Thailand – A multi-criteria decision analysis. Journal of Cleaner Production, 196, 400–410. https://doi.org/10.1016/j.jclepro.2018.06.060

Shelton, T. (2007). Greening the White House: Executive mansion as symbol of sustainability. Journal of Architectural Education, 60(4), 31–38. https://doi.org/10.1111/j.1531-314X.2007.00106.x

Siala, K., & Stich, J. (2016). Estimation of the PV potential in ASEAN with a high spatial and temporal resolution. Renewable Energy, 88, 445–456. https://doi.org/10.1016/j.renene.2015.11.061

Siew, C. C., Che-Ani, A. I., Tawil, N. M., Abdullah, N. A. G., & Mohd-Tahir, M. (2011). Classification of natural ventilation strategies in optimizing energy consumption in Malaysian office buildings. Procedia Engineering, 20, 363–371. https://doi.org/10.1016/j.proeng.2011.11.178

Siva, V., Hoppe, T., & Jain, M. (2017). Green buildings in Singapore; Analyzing a frontrunner's sectoral innovation system. Sustainability (Switzerland), 9(6), 1–23. https://doi.org/10.3390/su9060919

Sun, N., Cui, Y., Jiang, Y., & Li, S. (2018). Lighting and ventilation-based building sun-shading design and simulation case in cold regions. Energy Procedia, 152, 462–469. https://doi.org/10.1016/j.egypro.2018.09.254

Tan, P. Y., Wang, J., & Sia, A. (2013). Perspectives on five decades of the urban greening of Singapore. Cities, 32, 24–32. https://doi.org/10.1016/j.cities.2013.02.001

Thormark, C. (2006). The effect of material choice on the total energy need and recycling potential of a building. Building and Environment, 41(8), 1019–1026. https://doi.org/10.1016/j.buildenv.2005.04.026

Tong, Z. (2017). Review of the Application of Green Building and Energy Saving Technology. IOP Conference Series: Earth and Environmental Science, 100(1). https://doi.org/10.1088/1755-1315/100/1/012141

Tong, Z. (2020). Discussion on Application of Energy Saving Technology in Green Building. IOP Conference Series: Earth and Environmental Science, 446(2). https://doi.org/10.1088/1755-1315/446/2/022010

Umar, U. A., Faris Khamidi, M., Khamidi, M. F., & Tukur, H. (2012). Sustainable Building Material for Green Building Construction, Conservation and Refurbishing. Management in Construction Research Association (MiCRA), 29(May 2014), 5343–5350. https://www.researchgate.net/publication/233996708

Wang, M., & Yang, Q. (2020). Green building design based on 5G network and Internet of Things system. Microprocessors and Microsystems, November, 103386. https://doi.org/10.1016/j.micpro.2020.103386

Weinrich, L., Hubler, J. F., & Spatari, S. (2012). Urban water supply: Modeling watersheds and treatment facilities. Metropolitan Sustainability: Understanding and Improving the Urban Environment, 370–389. https://doi.org/10.1533/9780857096463.3.370

Wimala, M., Akmalah, E., & Sururi, M. R. (2016). Breaking through the Barriers to Green Building Movement in Indonesia: Insights from Building Occupants. Energy Procedia,

100(September), 469–474. https://doi.org/10.1016/j.egypro.2016.10.204
Xue, F., Lau, S. S. Y., Gou, Z., Song, Y., & Jiang, B. (2019). Incorporating biophilia into green building rating tools for promoting health and wellbeing. Environmental Impact Assessment Review, 76(January), 98–112. https://doi.org/10.1016/j.eiar.2019.02.004.