INVESTMENT AND CONSTRUCTION COST ANALYSIS ON NET-ZERO ENERGY BUILDING TECHNOLOGY

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Abstract— A research on the concept of the Zero-net-energy buildings, in Sarawak has been conducted. Even though this technology has been around for almost 10 years, many are still unaware of this technological advancement in the field of construction. This research paper covers the definition and the operations of a zero-energy building to ensure that a good understanding of the basis of this zero-energy building is obtained. Even though this type of building will be kinder and safer to the environment, there are disadvantages to it. Thus, the research includes the advantages and disadvantages of this technology. The goal of this research is to gain a deeper and further understanding behind this concept. By doing so, this concept may be applied to improve lives in the future. As for now, one of the closest examples in Kuching is focused on, namely the Sarawak Energy headquarters building located at the Isthmus. A thorough analysis of the overall building structure and other necessary aspects such as the power consumption and the cost-effectiveness of this building is conducted. Other than that, a comparison between in terms of the Building Energy Index (BEI) values, investment analysis and the construction costs the Sarawak Energy headquarters building along with another building of its kind, the University College of Technology Sarawak (UCTS) building in Sibu, Sarawak and a conventional building is carried out. Last but not least, a brief conclusion regarding the topic is drawn at the end of the report.

Keywords—Net-Zero Energy Building (NZEB); photovoltaic system (PV)

I. INTRODUCTION

With the ever increasing demand of electricity power all around the world, the rate of electricity production is definitely at a high level. At the moment, the main source for production of electricity is from the burning of coal. Since the concept of renewable energy has been introduced, more and more ways are being developed in order to reduce the dependence on coal burning to produce electricity. The implementation of renewable energy sources has clearly become the main challenge in the field of renewable energy. Many countries have started encouraging the people to make use of the renewable energy resources that are available in abundance, taking for example sunlight from the Sun. As the sunlight is available to almost everyone, many are encouraged to take the initiative of setting up their own solar panels at home. The energy produced from the sun will be converted to electricity. The produced electricity can then be used domestically. Any excess of energy produced could be sold to the government following certain requirements set by the government. Another way of implementing renewable energy resources on a larger scale would be the Net-Zero Energy Building (NZEB). What this basically means is that the building will generate power according to its own needs and consumption. This building will not be requiring any power injection from an external source. It will produce energy to be supplied to itself. Since the introduction of this NZEB, many have done research regarding its efficiency and the method of evaluating its overall efficiency. Through research, more and more ways have been developed to further improve its efficiency. By improving its efficiency, the actual definition of NZEB started to evolve as well.

One of the definitions of NZEB is that it can be defined based on the initial goal of the project. Deng and Wang (2014) states that another factor that defines a NZEB is the values being upheld by the team of designers working on the structure of the whole building [1]. Different design teams might have different weight put on certain values. By referring to their own set of values, this will create different NZEB definitions and construction. This article gave a basic method of performance evaluation of a NZEB. The authors provided a broader definition rather than a fixed method of evaluating. When conducting research on a NZEB, the elements that make up the whole building must be considered. These elements include the system of the building, the energy grid, and the weight system. According to Hassan (2011), the first thing to be done before commissioning a NZEB is to determine a goal or a boundary of on-site power to be produced for the usage of the building [2]. By having a clear goal, it would be easier for the design team to design a system that is able to produce that much power to be consumed. In order to be able to come up with this boundary, a balanced and clear calculation must be performed regarding the amount of generation and demand of that building. Once commissioned, the building system will feed on the power being produced on-site. In the case of excess in power generation, the power will be fed back to the grid. Another method of defining a NZEB is by studying the mechanism of its operation and some basic structures. The basic structures include building boundary, the period took for each evaluation and also the total estimated weight of the building as mentioned by Desideri et al [3]. In this technology driven world, the boundary of the building is no longer only a physical boundary; a virtual boundary can also be created. By having an extended virtual boundary, an important factor such as the power of the renewable energy will have more options to be chosen from. Comparing the evaluation method provided by the previously mentioned articles, Desideri et all presented a different perspective of NZEB. He emphasized more on building design itself rather than the goals and objectives of the design. As having or owning a NZEB can be said to be closely related to being able to run the building economically, many researchers and also owners prefer a method of defining a NZEB through its economical effects. The energy cost of a NZEB is definitely lower than a normal building due to its design. Instead of looking at the balance between the generation and demand of the building, the economic effects of the building become the defining point.

II. LITERATURE REVIEW

This section of the paper will focus on the basic or fundamental blocks in designing a NZEB. Some principles are also discussed. Advantages and disadvantages of NZEBs are presented.

A. Design of NZEB

Since the introduction of this concept years ago, many researchers have been continuously studying more and more advanced methods in producing NZEBs that are more efficient. The efficiency of NZEB can be define in terms of its cost effectiveness, balance between energy consumption and production and many more as previously discussed. In order for a NZEB building to be fully efficient, certain criteria in the actual design of the building must be considered. One of the methods in creating an optimal design of a NZEB is by setting certain design variables in the early design stage. Deng and Wang stated that these criteria, which should include both continuous and discrete will be monitored throughout the whole design and also simulation or testing stage [1]. One of the examples of the continuous variable is the thickness of the extra insulation layer to be added to the walls of the building. As for the discrete variable, the material and design of the windows to be installed in the building should be considered [4]. These variables are to be chosen based on the primary objective of the building. If the objective leans towards more cost-saving, a different variable, such as the type of materials to be used is to be considered [5]. As for reaching an objective in terms of power efficiency, more focus should be given to the design of the building as a whole. Once the primary objective of the building has been decided, only then the variables or the parameters can be determined. Simulations can then be done in order to test the design performance before the real construction work begins [5]. Hasan, on the other hand,, wrote that in a single objective problem, to set the optimum values for the predetermined factors requires a large number of research and also trial and error which is very exhaustive [2]. The results of the simulation of a single objective problem are usually analysed in terms of cost. If the pre-determined single objective is focused on the minimisation of one objective, then the ΔLCC is calculated. To calculate the value of the ΔLCC, the following formula is used;

$$\Delta LCC = \Delta IC + \Delta RC + \Delta OC \text{ [2]}$$

where ΔIC refers to the investment cost difference for the predetermined design variables, ΔRC represents the replacement cost difference caused by item replacements due to shorter life span as compared to building life and ΔOC refers to the operating cost difference due to energy consumption difference. Analysing all the costs will eventually lead to an optimisation problem as an objective that is cost orientated will naturally conflict with the targets. For example, building a NZEB require extra materials as compared to a normal building [2]. This will incur additional initial investment that is supposed to reduce future costs. With the simulation results and costs calculation done, it is then up to the management to decide on the feasibility of the project. Similar to Deng and Wang, Hasan also provided a basis for defining a certain goal or objective in the very beginning of the project. This defined goal or objective will determine the direction of the rest of the performance criteria of the building design. The design process gets more complicated if there are several objectives to be simultaneously achieved as stated by Desideri et al [3]. This situation requires a design that combines all the related issues or problems into one integrated problem to be resolved. In an integrated problem, factors such as conversion of energy, production of on-site energy vs overall consumption, connection to the grid are some of the few key factors to be monitored. To achieve an optimal design that satisfies all the factors, there will be some trade-off in the design of the building. Al Ajmi et al (2016) stated that these trade-offs might include indoor discomfort caused by minimising the Heating, Ventilating, and Air Conditioning (HVAC) systems and probably discomfort in the seating arrangement as to optimise indoor daylighting [6]. This is where this type of multiple objectives project becomes a conflicting project as previously mentioned by Desideri et al. In a situation where multiple objectives must be met, more considerations must be taken into account. The management of the building would have to make numerous decisions regarding the overall direction of the building. The next step is to simulate the building design with focus given to the earlier identified factors. The simulation approach that should be taken is the "combined simulation-optimisation" approach [2]. This approach combines the algorithms that will produce values of the variables at an optimal level with the dynamics of the building simulation program. These factors are monitored throughout the simulation process. Taking for example a multiple objective problem that includes minimising the ∆IC and the yearly demand for space heating simultaneously. To better analyse the simulation results, a cost-curve is used and from there, a solution that is cost-optimal can be found. When compared to a single objective problem, a multiple objective approaches yields better results with much less effort.

B. Passive approach to NZEB

As the name suggests, a passive approach to NZEB can be defined as taking measures or implementing strategies by considering the long-term outcomes that require little maintenance. This approach includes considering geometry and orientation of the building, high-performance building envelopes, passive solar heating, daylighting and natural ventilation. The overall geometry and orientation of a building are one of the key factors to be considered in order for NZEB to be achieved. Before beginning any construction works on a new building, careful planning and thought should be put into the geometry design of the building. The geometry of the building is part of the determining factor of the building's future power demand. Having complicated designs with no specific purpose will incur extra costs in the future and this will contradict the purpose of having a NZEB [3]. As for the orientation aspect of the building, it should consider how efficient the building will be in fully utilising one of the most abundant sources of renewable energy which the solar energy. By having an optimal building orientation, it will enable the building to maximise the energy from the sun for the PV systems and also hot water systems powered by the PV. As this is not necessarily applicable an existing building that plans to convert into a NZEB, for new buildings, the geometry aspect has to be considered. According to Straube, the building envelope is the physical structure of a building that is used mainly to separate the interior and exterior of a building [7]. The structures include walls, flooring, roofs, and fenestrations. Considering the building envelope in designing a NZEB, again the orientation is taken into account. With good orientation, the natural daylight can be fully utilised for indoor use during the daytime while also ensuring that the increase in solar heat is kept the minimum. This can be done by strategically planning the location of fenestrations to improve the ventilation of the area through natural ventilation. The implementation of skylights into the design of the building will enable the building to receive natural daylight.

C. Active approach to NZEB

Different from the passive approach, the active approach focuses more on current and on-going measures being implemented to achieve a NZEB. These active measures include the implementation of High-Efficiency HVAC equipment, ground-source heat pump systems, solar photovoltaics. wind turbines and much more [8]. The mentioned systems can be implemented both on-site and off-site locations but with the same purpose, which is to produce energy that is being demanded by the building. In other words, producing energy for own consumption and keeping the energy demand and production balanced. Having an efficient HVAC system will allow for savings in the range of 10%-40% of the costs incurred for this purpose. This percentage savings will differ according to the control settings set by the user. Before commissioning this system, there are factors to be considered such as the design goals, the size of the system (to ensure optimum operation), shifting of loads during peak hours and much more. Once everything has been considered, the settings of the HVAC can be done according to the needs and demands of the building together with its occupants. As for the implementation of the solar photovoltaic cells, this will ensure that the energy collected from the Sun is converted into electricity to supply the demand of the building. As Malaysia is a country that receives sunlight all year round, it would be a total waste to not be utilising this source of renewable energy.

Summarising Straube's paper, he discussed two ways of performance evaluation of NZEB. The first method being the passive method and the other being the active method. As the name suggests, the passive method focuses more on the long-term outcomes of the project. Deciding strategies for long-term outcomes requires a different approach as long term plans usually require less maintenance. Factors such as the building geometry and orientation must be considered in order to achieve long-term goals. This is important as this approach will ensure the direction of the building performance in the future. Different from the passive way, Straube further discussed the active method in his paper. This method is the opposite of the passive method as it focuses on current and on-going strategies being used in the building. These on-going efforts include installation of solar photovoltaic systems for the purpose of on-site energy production. This method is usually implemented on existing buildings in the process of converting to NZEB.

D. Principles of NZEB

To successfully achieve a status of an NZEB, there are key principles that if followed, will ease the process of turning into a NZEB. These principles will provide a path or a guide to reach that NZEB status. The first principle for NZEB would be defining the energy demand or the energy needs of the building [9]. Defining this energy demand simply means having a clearly known limit in the flow of energy that relates to the building operation. This operation accounts for operations that control and determines the quality of the energy with regards to the energy demand. To set the limit, it should be based on the total energy required by the building. Losses due to storage and distribution should also be considered in this.

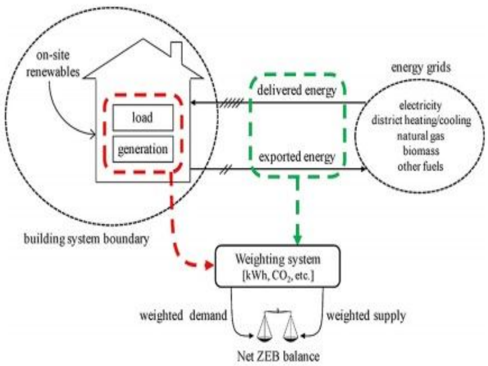

Figure 1 NZEB basic operating principle

Figure 1 shows the basic elements present in a NZEB. The basic elements should comprise of the system of the building, energy grid and also the weighting system [1]. Every component should be taken into account before a final design is decided upon.

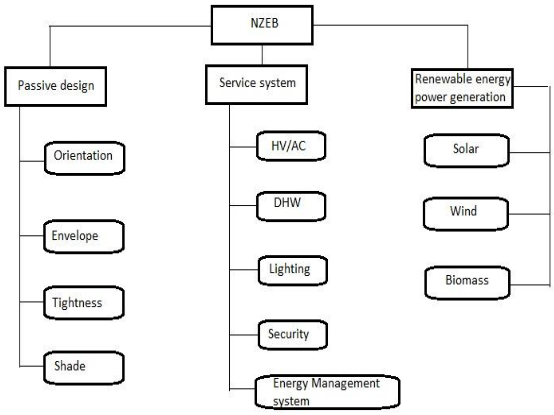

Figure 2 Power distribution in NZEB

The second principle to be followed is the share of the renewable energy. A boundary in the flow of energy that relates to the operation of the building that determines the calculation and measurement of the renewable energy share have to be made known by everyone [9]. This definition should also include guides on assessing this share. All energy produced on-site from renewable energy sources accounts for the eligible share for the renewable energy. This should include the total amount of energy needs plus all the losses of the system. In other words, the sum of energy that is being supplied to the building from its active supplies. Furthermore, the method of distribution of the energy being produced on-site should be clearly stated. The proposed distribution method of energy is shown in Figure 2. This is why the demand from each load has to be known before the distribution network is set up.As for the third principle, it focuses on the primary energy and the emissions of CO_2. Again, a boundary that defines the flow of energy boundary that relates to the building operation that determines the primary demand of energy along with the emissions of CO_2 has to be well defined. A guide on the methods of assessing these values should also be provided. The primary demand of energy with the CO_2 emission relates directly to the sum of the energy that is being supplied to the building directly from its active supply systems [9]. In the case of over production of renewable energy during a balanced condition period, the process of exporting the excess energy should be made clear by providing rules and regulations on this matter. From the research paper by Lopes et al, there are three important principles to be considered when designing a NZEB. All three principles cover the aspects of the needs and demands of the building, the operation of the building as a whole and also the steps taken to fully utilise the energy being produced by the building. The writer emphasizes the importance of having clear guidelines in designing a NZEB. These guidelines should be made as clear as possible to the people who are involved in not only building the building but also to the end users of the building. This is to not create any confusion or any chance of misconduct by irresponsible personnel in the future.

E. Advantages of NZEB

In recent years, more NZEBs are constructed around the world because of the advantages this type of building possesses towards the society and environment compared to conventional buildings [10]. One of the main advantages of constructing a NZEB is that the building owners would be unaffected by the increase in prices of energy sources in the future. According to Woo et al., the retail electricity prices in the United Kingdom electricity increased significantly after its liberalization [11]. Similarly, the price of electricity in Romania payable by both the industry and residents was increased by almost 8 percent in the year 2004 [12]. These trends may predict the continual increase of prices in the future. While many individuals are adversely affected by the increase in electricity prices, NZEB owners are less impacted because they have maximized the benefit of energy efficiency prospects. For instance, the Aldo Leopold Legacy Center in Wisconsin, United States uses approximately 30% of the energy that similar conventional building uses while having a 39.6-kW rooftop photovoltaic array that is capable of producing over 110% of the annual electricity requirements of the building [10]. Meanwhile, the Audubon Center in Debs Park in California, United States requires only 25 MWh of energy annually which converts to approximately five kWh per square foot [10]. The energy efficiency of these NZEBs shows that the building owners are not financially affected by the price increase in electricity. NZEBs are more environmentally friendly than conventional building because they do not contribute to pollution.

Conventional buildings rely on the grid for energy sources, and the energy is most likely generated from coal, the most widely used energy source in the world [13]. The burning of coal emits a number of gases that are harmful to the environment such as carbon dioxide, Sulphur dioxide, nitrogen dioxide and methane [14]. Other than that, a significant amount of ash is released into the atmosphere. It is reported that A 1 GW power plant that burns an average of 12,000 tons of coal a day produces approximately 2,400 tons of combustion fly ash [14]. The ashes contain numerous amounts of potentially toxic trace substance such as heavy metals and radionuclide which cause harm not only to the environment but to humans as well [14]. Therefore, NZEBs which use renewable sources of energy like solar power would not contribute to global pollution. This is because toxic gases and harmful ashes would not be created during the energy generation of the buildings.

Other than that, NZEBs are capable of providing better comfort to their occupants compared to conventional buildings because they have more constant interior temperatures. NZEBs are typically designed to be capable of for passive cooling and heating. For instance, the roof and alignment of the buildings would be designed in such a way whereby the windows get minimum sun exposure during the summer period when the sun is high - and maximum sun exposure during the winter months [15]. NZEBs can also be designed to comprise a network of heat-recovery ventilation which is capable of delivering fresh air and better climate control indoors while also conserving energy by reducing the demands of air conditioning systems [15]. Zeiler et.al. reported that a zero-net energy school building in The Netherlands has approximately 30% less carbon dioxide concentration compared to other buildings in the same area while their questionnaire results show people prefer the thermal comfort and indoor air quality of the school building as compared to the other buildings [16].

F. Disadvantages of NZEB

Even though NZEBs bring many benefits, some disadvantages are still present and has driven many parties away from constructing more of these buildings. One of the main flaws associated with NZEBs their high construction cost. The high initial cost is due to the steep prices of technology such as solar panels that allow the building to be self-sufficient [17]. Anderson et. al. estimated that a NZEB needs an additional investment of between MYR 33,795 and MYR 60,852 on top of regular building costs [18]. Meanwhile, Lackner et. al. reported that zero-net energy homes require technology prices to decrease by 13% each year or energy prices to increase by an equivalent quantity before the standard can be cost effective over the suggested life [19]. In short, it has been proven that the initial cost required to build a NZEB is high. As a result, many parties do not think it is justifiable to invest additional costs in the construction of their buildings. Besides the high initial costs, another reason NZEBs are not as feasible as conventional buildings are that there is a lack of builders as well as designers that possess the essential experience and skills to plan and construct NZEBs. As reported by Spiegel, Mr. Rey Montalvo, an energy consultant, discovered that the construction industry, in general, is currently falling behind in its knowledge of green energy. He added that all the constructors that he has worked with do not have much knowledge on zero-net energy concepts [20]. This lagging of knowledge in the construction industry regarding zero-net energy concepts may be due to the technology being fairly recent. Sustainable development that prioritizes preservation of environment and quality of life has only been broadly acknowledged globally in the last three decades [21]. Therefore, there has not been enough time for the construction industry to fully grasp and adopt the zero-net energy concepts thus far. As a consequence, constructing a NZEB is disadvantageous in a sense that finding a designer and builder with the necessary skills would prove to be difficult. NZEBs typically depend on solar energy as their primary energy source. However, strong sun intensity is required to capture solar energy optimally. For instance, solar energy capture is not optimal in extreme northern or southern Hemisphere. Burgess reported that the further away from the equator, the area where the solar beam spreads out increases. He also mentioned that the increase in distance from the equator would cause solar radiation to decrease because the solar radiation would have to travel further through the atmosphere [22]. Moreover, solar energy capture is also not optimal in shaded areas such as locations with many tall buildings or wooded surroundings. The shadows caused by the surrounding prevent the solar panels from receiving direct sunlight. The lower light intensity significantly decreases the power conversion efficiency of solar cells, which leads to poor energy generation [23]. In other words, a NZEB has to be situated in specific locations that are unobstructed from the sun to be efficient. Therefore, a NZEB is disadvantageous compared to conventional buildings in terms of the freedom of location.

GREEN BUILDING IN SARAWAK

This section of the research paper will focus on the process of studying the two NZEBs that are located in Sarawak. The first building is the Sarawak Energy Headquarters in Kuching and the other one is the UCTS campus in Sibu.

A. SEB Headquarters

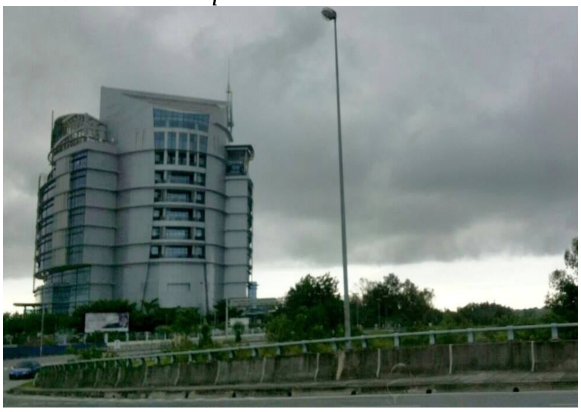

Figure 3 Sarawak Energy Headquarters

The Sarawak Energy Building is the headquarters for Sarawak Energy Berhad (SEB) as shown in Figure 3. SEB is the main electricity utility company for the whole of Sarawak since more than 100 years ago. The construction of the new headquarters was completed in the year 2012. It is a 9-storey building designed to accommodate its number of staff of approximately 1500 people.

1) Building Design

In order be able to achieve its target of becoming an NZEB, it is important that proper design measures be taken in the initial planning of the building.

For the SEB headquarters design, its north and south orientation plays a big role. In this case, as the building was to be designed to be energy efficient from the very beginning, the passive approach was taken and this allowed the designers more room to achieve the NZEB target. As Malaysia is blessed with an abundance of sunlight all throughout the year, it is only wise for the development and utilisation of the solar photovoltaic system. In the design of SEB headquarters, there are 6 areas where solar panels are placed throughout the entire premise. Four of which are located on roofs while two are located on the glass panels. The bigger area would be on the roof which covers approximately 985.2m^2. The figure 4 shows the current set-up for the solar panel areas in the premise [24].

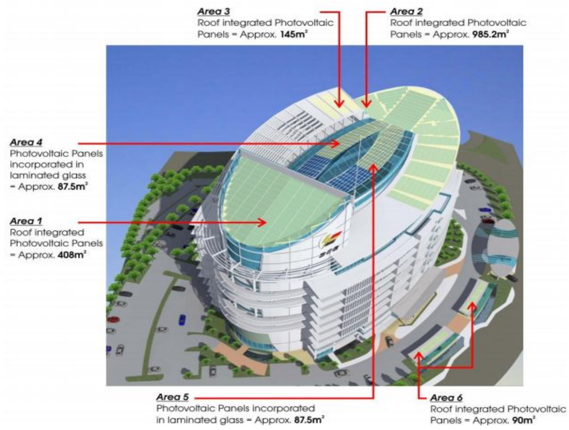

Figure 4 Solar panel areas in the premise

One of the reasons on the location of this building was that it will be fully exposed to the sun. There is no object that will an obstruction for the building to receive sunlight. The solar energy being produced is able to cover 2% of the building's energy consumption. Although this may be a small amount, but for a large building like this one, 2% could easily equal to a few hundred megawatts of power. By covering 2% of its own consumption, it is also able to reduce its carbon footprint.Another way of utilising the sunlight by the designers is the utilisation of natural day lighting as shown in Figure 5. In order to do so, façades are designed with split windows. Having split windows will enable more natural light to enter and illuminate the building during the daytime. By having sufficient light from the outside entering the building, the amount of electricity-powered light sources being turned on during the daytime can be reduced. This, in turn, will reduce the building's electricity consumption. All this exposure to sunlight is mainly due to the building's east and west orientation. Without proper planning, this direct exposure to sunlight can easily cause a high heat build-up in the building during the daytime. Thus, most of the windows of the building are made to face the north and south in order to minimize the amount of heat entering the building. As the side of the building that faces direct sunlight, which is along the east and west axis, the facades are protected with a layer of protection in the form of classed walls, extended sun-shading louvers and also double-glazed windows. By having these layers of protection, the solar heat gain can be reduced and at the same time, the amount of light entering the building is not affected. Keeping the amount of heat in the building is crucial in order to create a comfortable working environment for the workers in the building.

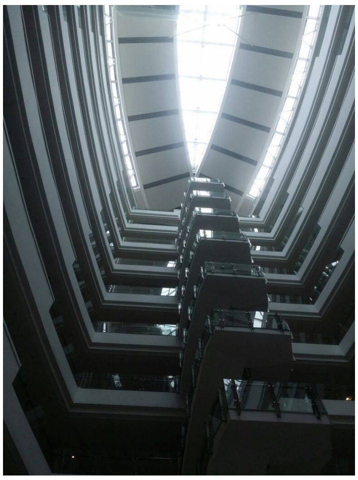

Figure 5 Use of natural daylight

Another passive approach taken by the designers of the building is the 'free cooling' method. This method utilises the spill-over air-conditioning coming for the offices. This technology allows the outflow of cool air from the offices into the central part of the building. The warm air inside the building will rise to the ceiling of the building which is equipped with louvres window panels. These window panels will facilitate the outflow of the warm air to the external surrounding. On the other hand, the cool air that moves to the lower part of the building will be kept inside through the usage of double-door air locks. This technology will enable the building to maintain a comfortable internal temperature without excessive usage of electrically powered cooling systems.

The energy consumption can also be reduced through the implementation of the daylight responsive lighting. The switches will be automatically turned on when the sensors sense that the amount of natural lighting in the room is too low. It will also turn itself off when it detects that there is sufficient sunlight illuminating the room. This smart technology will reduce the dependence on using electrical light sources by reducing its usage during the daytime.

2) Comparison between the old and new SEB headquarters

Once the construction of the new headquarters was completed, a period of one year was taken in order to be able to compare the overall performance of the new building. After a period of one year, the numbers were recorded and calculation was made. An official analysis was released and the overall results are shown in Figure 6.

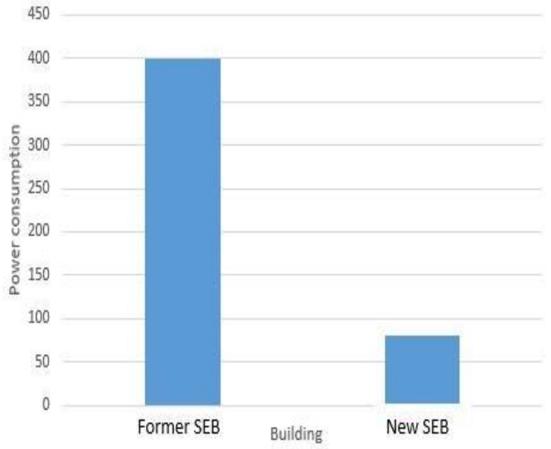

Figure 6: Building energy intensity of the Former and New SEB HQ

Based on the findings in Figure 6, it can be seen that a massive reduction is recorded in terms of power consumption between the two buildings. The annual energy consumption of the new building was at a staggering 400 kWh/m^2 while the new headquarters only recorded an overall value of approximately $90kWh/m^2$. Converting this value in terms of power consumption, an annual saving of 13000 MWh was made. With this high amount of reduction, the amount of CO_2 being emitted into the environment is approximately reduced by 11000 tonnes and this is equal to 5500 cars off the road.

B. UCTS Campus

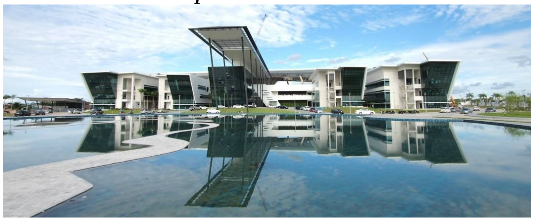

Figure 7 The UCTS campus

Figure 7 shows the UCTS campus which is located in Sibu, Sarawak [25]. The campus building was established in 2013. Similar to the Sarawak Energy building, the passive approach was used as the campus was designed with energy efficiency in mind from the beginning. It is the first university in Malaysia to attain the maximum level of accreditation in Green Building Index which is a Platinum rating [25]. This is because the building has the capability of reducing its energy consumption through the optimization of the orientation of the building as well as by decreasing the gain of solar heat with the building envelope, practicing the use of renewable energy and utilizing natural lighting [26]. The building is equipped with photovoltaic solar panels integrated throughout different locations of the roof with an approximate area of $200m^2$ each. The solar panels have multiple uses as they are able to provide shades for the occupants while being able to generate energy for the use of the building [25]. The walkways that connect different parts of the building, as shown in Figure 8, are well ventilated with fresh air so air conditioning systems are not required, thus saving energy [25]. The walkways also utilize ample amount of natural lighting which negates the use of artificial lighting that requires excessive energy [25].

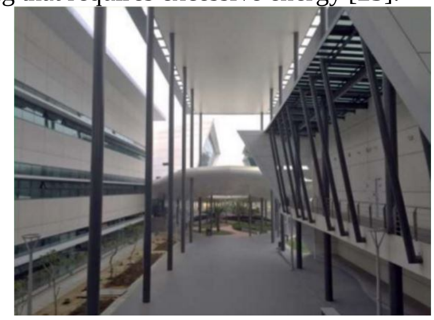

Figure 8 Well- ventilated walkways using natural lighting

Other than that, all windows of the building are constructed using double glazing glass [25]. A double glazing window is essentially a multilayered window that consists of glazing panes, a gas-filled cavity as well as an edge seal. The cavity between the panes allows the double glazing window to have a low thermal transmittance which can decrease the demand for cooling energy by around 11.1% as compared to a conventional window [27]. All artificial lightings in the building are light emitting diodes (LEDs) which consume less energy than regular light bulbs. The lighting system is paired with motion sensors which would further conserve energy by switching off lights automatically when a room is vacant [25]. According to Chua, the vice-chancellor of the university, Prof Datuk Dr Abdul Hakim announced that the building uses less than half of the energy used by a conventional building of its size.

C. Building Energy Intensity

1) SEB Headquarters

In order to evaluate the effectiveness of the new SEB headquarters, a study on the overall consumption of the building from the year 2012 up to 2014 was done [24]. The data collected from this study is to enable the comparison of this building with another non-green building with approximately similar size or total area.

Table 1: SEB yearly power consumption

Description	2012	2013	2014
Total Building Energy Consumption (RM/year)	1,082,609.70	1,284,088.50	1,216,025.40
Total Building Consumption (kWh/year)	3,600,459	4,272,055	4,045,178
Gross Floor Area per m^2	59388	59388	59388
Building Energy Intensity (kWh/year/m^2)	61	72	68

From Table 1, an average value of the Building Energy Intensity is calculated as 67. This value is then used to plot the graph of power comparison between the SEB headquarters and other conventional buildings. Figure 9 shows the comparison in terms of Building Energy Intensity (BEI) of SEB headquarters and other conventional buildings. The BEI values of the conventional buildings were extracted from a study of the average energy use intensity by building type in the United States of America [28]. The graph clearly illustrates the fact that the SEB headquarters recorded the lowest value of BEI among the other buildings. Having a lower BEI shows that a building consumes less energy within a period of time. In fact, the SEB headquarters only uses approximately 22% of energy that a conventional office in USA uses. Thus, it can be said that SEB can be considered to be successful in its effort in becoming a NZEB.

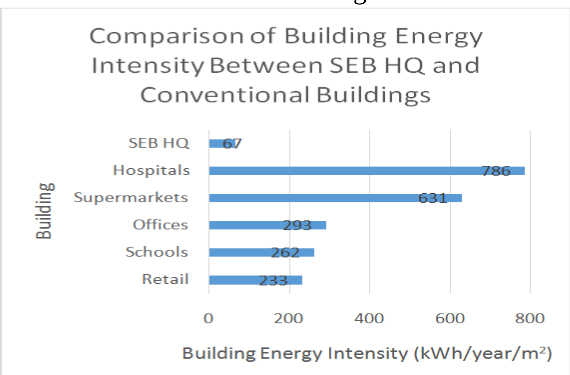

Figure 9 Comparison of Building Energy Intensity Between SEB HQ and Conventional Buildings

2) UCTS Campus

In its effort of becoming a NZEB, the UCTS Campus has definitely invested a lot in this project. Implementations of solar panels, usage of double glazed windows and maximizing usage of day-light are just a few of the steps that they have taken to achieve their goal [25]. In a published newspaper article, Chua discussed the success of the UCTS Campus in reducing in overall energy consumption.

According to Chua, the UCTS campus has succeeded in reducing up to 50% of its annual energy consumption through this NZEB project [29]. Assuming that a typical school or campus building records a Building Energy Intensity of 262 [28], the UCTS Campus would then have a value of half of that, which is 131. This is based on the fact that the UCTS Campus has reduced its energy consumption by 50%. This value is then used to compare the BEI values between the SEB headquarters and the UCTS Campus.

D. Comparison of Construction Costs

In this section, a brief comparison in terms of construction costs between the SEB headquarters, the UCTS Campus and a conventional building is done. This comparison will be used as a basis of evaluating the cost-effectiveness of the building.

3) SEB Headquarters

As discussed by Pilo in a newspaper article, the construction cost of the SEB headquarters is RM200 million while it has a floor area of 59388m^2 [30]. Meanwhile, the construction cost for an average standard office in Malaysia is RM1596 per square meter [31]. Therefore, if the SEB headquarters was constructed without any implementation of green technology, the building would cost approximately RM95 million. It is evident that the actual construction cost is around RM104 million higher due to the implementation of green technologies. This additional cost is due to the fact that more technologies are required to be implemented in order to be able to run as a NZEB. The high initial overall construction cost of a NZEB has long been a debate among researchers as this factor will determine the worth of the total project investment [21].

4) UCTS Campus

It is stated that the construction cost of the UCTS campus is approximately RM357.7 million [32] while the floor area of the campus is estimated to be around 300184m^2 [33]. Meanwhile, the construction cost for an average standard school or university in Malaysia is RM762.50 per square meter [31]. Therefore, if the UCTS campus was constructed without any implementation of green technology, the building would cost approximately RM228.89 million. Again, this RM128.81 million difference between the construction cost of a NZEB and a non-NZEB is definitely one of the factors causing the lack of desire in building a NZEB. This is caused by the fact that not all corporations and organizations are fully equipped financial to be able to proceed with a project of this scale. Even though cost-wise a NZEB project might not seem like a good short-term investment, the profits that it will generate in the long run will eventually benefit the owner and also the occupants of the building.

E. Comparison of Energy Consumption Costs

This section of the research paper will detail the annual energy consumption costs of the SEB headquarters and the UCTS campus. Annual energy consumption costs for its conventional building counterparts are also done for comparison purposed. The values calculated for the UCTS campus and the conventional buildings are approximated using assumptions made from Table 1. To calculate the annual energy consumption of a building, the average building energy consumption in terms of monetary expense is divided by the average BEI value of the building. This will yield the value of 17,824.496 RM / year / BEI. This value obtained is then multiplied with the respective values of BEI of the building. The resultant value from this multiplication will yield the final annual energy consumption cost.

5) SEB Headquarters

As summarized in Table 1, the average annual energy consumption cost between 2012 and 2014 is RM1,194,241.20. According to [28], the estimated annual energy consumption cost of a standard office is calculated to be RM5,222,577.33. There is a major difference of RM4,028,336.13 in terms of the energy consumption. From these values, a payback period of 25.82 years is estimated for SEB. In other words, the investment that SEB has made in building the new headquarters will eventually be fully recovered within the time of approximately 26 years. When discussing the lifespan of a building, 26 years is not considered as a long period to recover the construction costs. Furthermore, it is only normal that an investment of this amount would require a longer payback period.

6) UCTS Campus

The annual energy consumption cost of the UCTS campus is estimated to be approximately RM2,335,008.98. According to [28], the estimated annual energy consumption cost of a typical school or campus building is calculated to be RM4,670,017.95. There is a difference of RM2,335,008.97. Payback period is 55.16 years. In comparison with SEB, the UCTS campus requires a longer payback period. This longer payback period is caused by the higher value of BEI of the UCTS. Having a higher BEI value signifies that even though UCTS campus is a NZEB, it still has a high amount of energy consumption when compared with SEB. Although it will take UCTS a longer time to recover its investment for this project, this does not reduce or affect the worth of the initial investment.

F. Comparison between SEB Headquarters and UCTS Campus

As discussed earlier, the SEB headquarters recorded a BEI value of 67 while the UCTS Campus is assumed to record a BEI of 131. Comparing these two values, there is a major difference of 64. There are few factors to be considered in explaining the gap between the BEI values of these two buildings. The first factor to be considered is the commencement of the building operation. The SEB headquarters formally began its operation in the year 2012 while the UCTS Campus only started in late 2013. This makes the operation time to be about over a year apart. With this much difference in terms of operation, the building which started earlier would obviously be able to generate more energy for its own consumption. By doing so, more of the overall energy consumption is reduced. Thus, this corresponds to the lower value of BEI that SEB headquarters has recorded. The next contributing factor to the lower value of BEI for SEB compared to the UCTS campus is the level of expertise available at respective places. SEB is widely known as the sole supplier, generator and distributor of electricity for the whole of Sarawak. Thus, with this large scale of operation, SUB certainly has its own experts in various fields related to the electricity industry. Furthermore, with the increasing awareness on the implementation of renewable energy, SEB has certainly been one of the leaders in this field in Sarawak. Thus, this actually enabled the SEB headquarters to be designed by not only the consultants, but also its own experts and specialists. With a high number of experts working on the design definitely ensured the functionality and the overall effectiveness of the building in the long run. The UCTS campus on the other hand, might have the level of expertise that the SEB has. Due to the lack of expertise in this field, UCTS might have depended solely on the expertise provided by the project consultant. By not having somebody from UCTS itself working on the project alongside the consultants, certain aspects of the design might have been overlooked. By overlooking certain aspects not only from the design wise, but also the whole planning of the project, the overall effectiveness and functionality of the UCTS campus could have been compromised. With the reduction in effectiveness, this could be used a basis of explaining the higher value of BEI for the UCTS campus. Furthermore, this higher value of BEI will incur a longer period for UCTS to have a return on the investment made in this project.

The overall financial requirement of the project could also be considered as one of the factors affecting the BEI values for each building. The SEB is an established entity that runs on a large scale in the field of electricity distribution. Being an established entity such as the SEB would definitely create an access to a bigger amount of financial support. Even though the support would partly come from the government, the SEB could have an access to its own pre-existing budget. Having this extra amount of financial support created a larger window for SEB to explore all the possibilities in building its own NZEB [19]. Having the advantage of limitless possibilities, SEB have definitely succeeded in being able to obtain its status of NZEB. As for the UCTS Campus, financial issues could have been one of the main obstructing issues in the overall design project. Although this project by UCTS is supported by the government, UCTS might have been depending solely on this support. Comparing the scale of operation of the SEB and UCTS, an obvious difference can be seen. Due to the smaller scale of operation of UCTS, this might have created a limited access to extra financial support in the form of its own pre-existing budget thus limiting the possibilities to be explored in designing a NZEB. Having a limited window of possibilities would definitely have an impact on the effectiveness of the building. This reduction in effectiveness contributes directly to the higher value of BEI.

CONCLUSION

To sum up the entire report, there are two ways to achieve a NZEB target, the active and passive approach. Some advantages of NZEBs compared to conventional buildings include being unaffected by a price increase of energy sources, having increased comfort due to more constant interior temperatures and not contributing to pollution. On the other hand, NZEBs require higher initial costs than that of conventional buildings, while the construction industry lacks the necessary skills or experience to build NZEBs. Solar energy capture by NZEBs can only be optimized in locations with high solar intensity such as near the equator. The NZEBs in Sarawak are the Sarawak Energy building and the UCTS campus. They share similar design characteristics which allows them to generate renewable energy while reducing energy consumption.

To summarize the study that was conducted, the SEB headquarters and UCTS campus have a comparatively low BEI value of 67 and 131 respectively, which signifies the low energy consumption of the buildings. While the construction costs of both buildings were proven to be higher than that of conventional buildings, the higher costs are justified by the monetary savings benefited from the lower energy consumption. From calculations and estimations, the savings are able to cover the extra costs in construction within 26 and 56 years for the SEB headquarters and UCTS campus respectively. The NZEB technology is a good solution to overcome the global energy crisis while promoting the use of renewable energy. NZEBs have a great potential in creating a better world for us to live in as due to their many advantages as discussed previously. However, it is apparent that the NZEB technology has not been practiced widely in the world as of yet. This statement is supported by the fact that the state of Sarawak has only two NZEB buildings. The low adoption rate of the NZEB technology may be because of the disadvantages present. Hence, more time and research is required to overcome these shortcomings.

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