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Green Building Design Features For A Better Smart School: Lesson Learnt From Geo and Leo Office Buildings

S.N.Kamaruzzaman¹, R.Sulaiman¹ & L.Chi-Hin¹
¹Building Performance and Diagnostic, Faculty of Built Environment,
University of Malaya, 50603 Kuala Lumpur
Correspondence email: queenofkuji@gmail.com

Abstract

There are many evidences based on previous researches that buildings are responsible for the global warming and climate changes due to the carbon footprint, which resulted not only from the construction activities but also throughout buildings lifecycle. As for schools, people need to build new buildings as to cater the growing demands of young generation. Apart from new constructed buildings, the existing one also need to be upgraded and improved from time to time as to be equivalence with current demand especially in terms of comfort and energy efficiency. Contrary to office building, Malaysia does not have a standard for an energy efficient school building or so-called green school building. Therefore, this paper focuses on the Green Building Design being applied in the office buildings with the aim that it can be a basis for a smart and green school building. The focus of the research will be on the relationships between the design applied and level of energy efficiency performance in GEO and LEO buildings. The findings shows that orientations, shading devices, interior layout, roof and walls insulation, ventilation system and innovative windows are some of the solutions for an effective smart building.

Keywords: Green building, passive design features, energy efficient,

1.0 Introduction

On 24th July 2009, The Prime Minister of Malaysia, Dato’ Sri Mohd Najib has launched Green Technology Policy 2009 stressing on energy efficiency and green building design that the country heading towards in the future. Some of the approaches taken were setting up a green technology agency, promoting foreign investments, allocating incentives for students who pursuing green technology, and provision for R&D (Oh et. al, 2010)

A sustainable building, or green building is an outcome of a design which focuses on increasing the efficiency of resources used (energy, water, and materials) while reducing building impacts on human health and the environment during the building's lifecycle through better orientation, design, construction, operation, maintenance, and removal (Frej, 2005). A successful green design is a building that cleans its own air, save its own water, and produces its own energy, makes it off grid from power generator stations that emit greenhouse gases and heat. A green design also covers installation, verification and monitoring of HVAC, lighting and other equipments and the use of renewable energy.

The term “green” is essentially a synonym of sustainable, but it is frequently used more loosely than the term sustainable (Resnick, 2009). While the green building movement in Malaysia is still in its infancy, the green building revolution is happening around the globe, which fuels by the understanding of the impacts on the environment and human health. This revolution is further fueled by the consciousness of the limited time for the world to counteract...
against the dangers of climate change and global (Yudelson, 2007). The revolution can be tracked down to numerous causes over the years, just as the seeds of the independence of Malaysia were planted decades before the country erupted into open rebellion.

Malaysia was listed as the bottom 10 country of cleanliness in climate index. The design of our buildings will determine the energy efficiency of the buildings. However, the green building design concept is still not popular among the construction field. There is a lack of awareness among the commercial financial institution and the absence of viable projects on the benefits of this design. This condition may contribute to the growth climate changes as well as global warming and thus indirectly affect the welfares of human race in the next generation.

The Green Building Index Malaysia defined a green building as a building designed to be efficient of resource use, while reducing building impact on human health and the environment throughout the building’s lifecycle. Whilst Frej (2005) defined green building as “an outcome of a design which focuses on increasing the efficiency of resource use – energy, water, and materials – while reducing building impacts on human health and the environment during the building’s lifecycle, through better sitting, design, construction, operation, maintenance, and removal” (p. 4).


Looking back to the literatures (Resnick, 2009; Frej, 2005; McDonald, 2005; Yudelson, 2007; Cole et al, 2000; Kats, 2003), the more common terms used by the industry to discuss about the “environmental friendly” building matters are “Sustainability”, “Green Building”, “Holistic Whole Building Design” and others. However there is few or no definition that had been set by the industry about the term “Green Building Design”. In this paper, the term “Green Building Design” is used to reflect the initiatives and approach of the Malaysia industry. The reason why the term “Green Building Design” is used in this paper is to identify the passive approaches that integrate in an innovative building to achieve an energy efficient vision. In which the term “Passive Approach” is often related to the “Design” of one building. In addition, such passive approaches were one of the major criteria to realize the Green Buildings that will then advanced to Sustainable Buildings and Regenerative Buildings. It was from thus intention and relations that the “Green Building Design” is being derived. Therefore, the term “Green Building Design” in this paper, and thereon after throughout the whole project, is defined as: the passive design approaches integrated in a building that to achieve the objectives of a Green Building, in the context of reducing negative impacts on the environment and ecosystems. Hence, Green Building Design in Energy Efficiency (EE) means that the passive design approaches integrate into a building in order to achieve a very low energy consumption state and utilizing the still conventional energy spring from fossil fuel efficiently.

In order to deeper clarify the title, Green Building Design is the elements that are permanently attached to or part of the building design such as building orientation, building envelope, shading device, innovative windows, roof and wall insulation etc. These features are
often related to the passive cooling, lighting and ventilation of a building, which in turn contribute to the EE of the building.

A review on passive design listed that passive cooling, ventilation, day lighting, roof and wall insulation and interior space layout are the features that widely implemented in green building design (Azizi and Adnan, 2008). The concept of Green Building Design is a vital approach to achieve EE vision in a building. By integrating this concept early in the design stage will greatly reduce the cost for development as well as maintenance.

Normally to assess whether these green features are benefitted in achieving an energy efficient building, the management will look into the building’s energy consumption. The energy consumption in buildings for a green building is given in terms of the Building Energy Index or BEI. Based on Ahmed (2008), the Malaysian Ministry of Energy, Water and Communication (MEWC) or previously known as the Ministry of Energy, Communication and Multimedia (MECM) before the year 2004; introduced the Guidelines for Energy Efficiency in Non-Domestic Buildings in 1989 which was meant to be a building code of practice. The guidelines now have been renamed as the Malaysian Standard MS 1525:2001 and further improved in 2007.

Further, the Green Building Index in Malaysia was introduced on Jan 3, 2009 (Oh and Chua, 2010). It holds the distinction of being the first and only non-governmental and profession-driven green-rating tool developed for the tropical climate. The GBI’s ultimate goal is to reduce the carbon footprint of Malaysia’s urban cities. With this index in place, buildings in Malaysia can now be assessed and guided to reduce and minimize their impact on the environment. Based on Oh et al (2010), the index rates green buildings on six criteria which are energy efficiency (35%); indoor environmental quality (21%); sustainable site planning and management (16%); materials and resources (11%); water efficiency (105); and innovation (7%). Depending on the score, buildings will be rated accordingly as as platinum (86+), gold (76 – 85), silver (66 – 75) and certified (50 -65).

From the six key criteria, Energy Efficiency represents the highest marks. This criterion encompasses the design (25%); commissioning (5%); and also verification and maintenance (5%). Thus, we can see that Energy Efficiency is the crucial part of making a building green or sustainable; yet the design decides the energy efficiency of a building.

In hot tropical climate like Malaysia for instance, the cooling load for buildings is usually at its highest at mid day. This makes the mechanical equipment work harder to keep the occupants comfortable, which leads to greater electricity and hence energy consumption (Jain, 2009). Every 1K rise in the daily maximum temperature leads to 2 to 4% increase in peak urban electricity demand for cooling starting from the 15-20 °C (59-68 °F) temperature range (Akbari, 2001). Thus, it is important for us to make sure that these increments would not lead to higher energy consumption and thus the effort of making energy efficient building is just a waste.

2.0 Materials And Methods

This research adopts qualitative method, which only carefully selected buildings will be studied by interviewing their managing department and analyzing previous records and documents. No
A structured questionnaire survey to the public will be conducted due to the lack of knowledge about green among the public sector. However, semi-structured and open end questionnaires were prepared for interview sessions. The questionnaires are shown in Figure 1 below.

### Figure 1: Questionnaires used for the case studies

Case study selection was based on three criteria.

- **Energy Efficient**: To include buildings that consumes energy efficiently.
- **Green Building Design**: To include buildings that integrates passive approaches into the design such as building orientation, interior space layout design, roof and walls insulation etc.
- **Building type/function**: To include buildings focus on a specified function.

Observations were carried out in order to identify the location of green design integrated in the subject buildings; what is the level of comfort inside the building; and how such design helps to reduce the energy consumption of the building. Photographs were taken for visual purpose.

### 3.0 Results And Discussion

Despite the most advance EE features integrated in the GEO Building, the building was only GBI certified, instead of Gold or Platinum award. The limitation in the research is that the available energy performance of the studied buildings was not up to date. The data obtained from the LEO Building was data monitored in 2005. While the buildings have been fine-tuning from time to time in order to achieve a better energy performance, therefore the data such as the building energy index (BEI) is believed to be energy efficient than the data shown in the this chapter. However, such fine-tuning often involved only with the active EE approach and human behavior. Hence, the data studied can be considered still pertinent for this research.
The PTM Green Energy Office Building (GEO Building), previously known as Zero Energy Office (ZEO Building), located in Bandar Baru Bangi, Selangor, Malaysia, is an administration-cum-research office for the Malaysia Energy Centre. The GEO Building is officially the first and only completed GBI Certified building to date in Malaysia, which is why it was chosen to be the case study. Though being a pilot project, the building marked another milestone towards greater promotion and adoption of sustainable building concept in the Malaysian Building sector. According to PTM’s officer, it is the only such building in Malaysia that integrates the Energy Efficiency (EE) and Renewable Energy (RE) in one working demonstrator building to date.

Meanwhile the LEO building is the first government building to be built with green building design in context of energy efficiency. As a showcase building like the GEO Building, the LEO Building demonstrates the EE features so that other buildings can replicate such measures, make it public or private sector. Although the LEO Building is not a certified Green Building by any available Green Building Rating System, it was chosen to be one of the case studies of this research due to its most advances EE Green Building Design features in the region to date. The building displays integration of the best EE designs, which will be discussed together with the GEO Building in the next section. The buildings are shown in Figure 2 and their background is tabulated in Table 1 below.

Table 1: Building background

<table>
<thead>
<tr>
<th>Building Owner</th>
<th>PTM GREEN ENERGY OFFICE BUILDING</th>
<th>LEO BUILDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Owner</td>
<td>Pusat Tenaga Malaysia</td>
<td>KETTHA</td>
</tr>
<tr>
<td>Gross Floor Area</td>
<td>4,000 m²</td>
<td>38,606 m²</td>
</tr>
<tr>
<td>Total Number of Storey (excluding roof-top and basement)</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Commencement Date of Building Operation</td>
<td>September 2004</td>
<td>September 2004</td>
</tr>
<tr>
<td>Primary Use</td>
<td>Administration-cum-research office for the Malaysia Energy Centre</td>
<td>Administration &amp; Research for KETTHA</td>
</tr>
<tr>
<td>Differences</td>
<td>(BIPV) panels are all integrated into the building design and connected to the National Electricity (TNB) grid which contribute to Zero Energy Office</td>
<td>Did not integrate active Solar Technology which only lead to Low Energy Office</td>
</tr>
</tbody>
</table>
3.1 Green Building Design Elements

Table 2 below shows the integration of several passive green designs that enables the buildings achieve very low energy characteristics. The table shows the different approach but yet still fall under the same passive design features.
Table 2: Green Building Design Elements in the PTMM GEO and LEO building

<table>
<thead>
<tr>
<th>Overview</th>
<th>PTM GREEN ENERGY OFFICE BUILDING</th>
<th>LEO BUILDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>integrates passive green design</td>
<td>integrates several passive green design</td>
</tr>
<tr>
<td></td>
<td>integrates EE active system (ie EE office equipment; EE IT Network &amp; server room; EE air conditioning and ventilation; floor slab cooling; Chilled Metal Ceilings; Ice storage cooling system; and controls &amp; sensors)</td>
<td>Active EE system in the building includes innovative air-conditioning system; lighting system; energy efficient office appliances; comprehensive energy management system; as well as mechanical ventilation system Installed with solar photovoltaic’s system that generate Direct Current (DC) and will be diverted to local loads in the building Rainwater harvest system from the secondary roof helps to reduce water consumption.</td>
</tr>
<tr>
<td>Building orientation</td>
<td>Façade facing north and south</td>
<td>Orientated to the North and the South</td>
</tr>
<tr>
<td>Sun shading devices</td>
<td>Large overhang at west facing windows Eastern façade does not have any windows or doors facing directly to the east to avoid direct sunlight</td>
<td>Larger shading on the eastern façade Exterior shading over the windows</td>
</tr>
<tr>
<td>Windows design</td>
<td>Double-glazing windows at north and south facing façade Double-glazing windows and internal blinds at west facing façade 50% light transmission and 25% heat transmission See Figure 3a and Table 3</td>
<td>Punch hole window façade in the lower floors, and curtain wall windows with exterior shading louvers in the upper floors. (Figure 5) Windows area are about 25-39% of the façade area no windows on the western façade but with 12mm thick light green tinted glazing</td>
</tr>
<tr>
<td>Interior layout</td>
<td>Open space concept with all the workstation are positioned near the windows where daylight is available Meeting rooms, facility room and stores are located at the centre Ground level is reserved for the publics Lower ground is mostly consist of M&amp;E rooms, with other facilities</td>
<td>Open space concept, where all the workstations are concentrated along the border as well as the atrium area in order to have the maximum daylight Secondary functions are consigned to the inner part, where artificial lighting is needed.</td>
</tr>
<tr>
<td>Daylight design</td>
<td>Set to 100% daylight during daytime Integrates mirror light shelf, roof light and skylight system respectively inside the building See Figure 3b</td>
<td>Managed to achieve 65% visible light transmission and allows only 51% of the heat Using a combination of exterior shading and tinted glazing The atrium allows daylight access to the central of the building See Figure 6</td>
</tr>
<tr>
<td><strong>Roof and wall insulation</strong></td>
<td><strong>Ventilation system</strong></td>
<td><strong>Others</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Adequate insulation at the roof and wall particularly the western and eastern façade &lt;br&gt;The building is airtight in order to achieve low cold air leakage &lt;br&gt;100mm thermal insulation in East and West walls; 200mm roof insulation, 200mm thermal insulation in ground floor slab &lt;br&gt;See Figure 4</td>
<td>District cooling system; mainly mechanical ventilation</td>
<td>Skylight system; Assisted day lighting</td>
</tr>
<tr>
<td>Insulated with 200mm aerated concrete block with 15mm plaster on both sides, together with light colours on the exterior surface &lt;br&gt;The envelope of the building uses lightweight concrete walls that have an insulation value 2.5 times better than that of a conventional brickwall &lt;br&gt;Flat roof of the building is 100mm thick reinforced concrete with 50mm thick polystyrene insulation of insulation &lt;br&gt;Canopy roof attached above the roof surface standing as a secondary roof &lt;br&gt;Green landscaping along the boundary of the roof</td>
<td>Stack ventilation (Atrium)</td>
<td>Natural ventilation system in the LEO Building through its thermal flue at the roof top, which creates the thermal stack effect. &lt;br&gt;Black painted walls and vents of the thermal flue chimney</td>
</tr>
</tbody>
</table>
Figure 3: The glazing system in GEO building (a) and the daylight design (b)

Figure 4: Roof and wall insulation of GEO Building

Table 3: Typical values of the double-glazing windows

<table>
<thead>
<tr>
<th>Description</th>
<th>Heat %</th>
<th>Light %</th>
<th>U-Value W/m2K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>85</td>
<td>85</td>
<td>6</td>
</tr>
<tr>
<td>Single, tinted</td>
<td>25</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Double</td>
<td>75</td>
<td>75</td>
<td>3</td>
</tr>
<tr>
<td>Double, spectrally selective, low- emissive, gas filled</td>
<td>25</td>
<td>50</td>
<td>1</td>
</tr>
</tbody>
</table>
3.2 Energy Performance

Due to the limitation of the research, the detail up to date energy performance of this building was not available to obtain. However, the Pusat Tenaga Malaysia (PTM) claims that the BEI achieved by the building is 65 kWh/m²/year. It is the lowest BEI in Malaysia to date. Referring to the illustrated energy index in Figure 6, the air-conditioning system is still the highest energy consuming factor, but obviously much lower than the conventional buildings as well as the LEO Building. Resulting from the daylight design of the building, the lighting system consumes only less than 5 kWh/m²/year from the total energy consumption, which very much less than the other buildings.

The EE features performance of the LEO Building has been monitored by MECM themselves since October 2004. The data is covering the period from 1st January 2005 to 31st December 2005 (Table 4 and Figure 7) which is all available from the KETTHA official website. The average electricity consumption was 4,532 kWh/day while the total monitored energy consumption was 6,000 kWh/day. Derived from the total energy consumed in the building, the monitored building energy index (BEI) is 114 kWh/m²/year, based on an air-conditioned area of...
19,237 m² and actual operation of 2,930 hours in the first year of observation. A study conducted by Malaysia Energy Centre in 2003 on government buildings with conventional design illustrated that energy consumption is typically 62% air-conditioning, 18% lighting and 20% plug loads. In contrast, the energy for air-conditioning represents 45%, lighting 21% and equipment 34% of the total energy consumption of the LEO Building.

![Figure 7: Comparative Building Energy Index of typical, LEO and GEO Building](image)

Table 4: Energy Data in 2005 for LEO building

<table>
<thead>
<tr>
<th>Month</th>
<th>CHW ton/h/day</th>
<th>CHW kWh/day</th>
<th>GS02 kWh/day</th>
<th>GS04 kWh/day</th>
<th>Electricity kWh/day</th>
<th>Total Energy kWh/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1.800</td>
<td>1.320</td>
<td>1.342</td>
<td>2.816</td>
<td>4.158</td>
<td>169,824</td>
</tr>
<tr>
<td>February</td>
<td>1.852</td>
<td>1.358</td>
<td>1.421</td>
<td>3.102</td>
<td>4.523</td>
<td>164,682</td>
</tr>
<tr>
<td>March</td>
<td>2.141</td>
<td>1.570</td>
<td>1.441</td>
<td>3.168</td>
<td>4.609</td>
<td>191,566</td>
</tr>
<tr>
<td>April</td>
<td>2.169</td>
<td>1.591</td>
<td>1.462</td>
<td>3.305</td>
<td>4.767</td>
<td>190,721</td>
</tr>
<tr>
<td>May</td>
<td>2.229</td>
<td>1.634</td>
<td>1.475</td>
<td>3.218</td>
<td>4.693</td>
<td>196,147</td>
</tr>
<tr>
<td>June</td>
<td>2.133</td>
<td>1.564</td>
<td>1.445</td>
<td>3.314</td>
<td>4.759</td>
<td>189,684</td>
</tr>
<tr>
<td>July</td>
<td>2.167</td>
<td>1.589</td>
<td>1.455</td>
<td>3.337</td>
<td>4.792</td>
<td>197,810</td>
</tr>
<tr>
<td>August</td>
<td>2.059</td>
<td>1.510</td>
<td>1.463</td>
<td>3.152</td>
<td>4.614</td>
<td>189,840</td>
</tr>
<tr>
<td>September</td>
<td>2.251</td>
<td>1.651</td>
<td>1.461</td>
<td>3.183</td>
<td>4.644</td>
<td>188,830</td>
</tr>
<tr>
<td>October</td>
<td>1.858</td>
<td>1.362</td>
<td>1.409</td>
<td>2.880</td>
<td>4.289</td>
<td>175,204</td>
</tr>
<tr>
<td>November</td>
<td>1.774</td>
<td>1.301</td>
<td>1.360</td>
<td>2.934</td>
<td>4.294</td>
<td>167,857</td>
</tr>
<tr>
<td>December</td>
<td>1.731</td>
<td>1.269</td>
<td>1.388</td>
<td>2.859</td>
<td>4.247</td>
<td>171,001</td>
</tr>
</tbody>
</table>

Mean kWh/day: 2,014 1,477 1,427 3,106 4,532 6,009
Total per year kWh: 734,974 538,981 520,790 1,133,544 1,654,334 2,193,164
Total BEI kWh/m²: 114.0
Both being the government’s showcase buildings in terms of Energy Efficiency, the GEO Building and LEO Building demonstrated equality in the Green Building Design approach, which they share common passive design in several items such as the building orientation, building envelope shading, day lighting design etc. However, the GEO Building overwhelmed the LEO Building in some cases. In order to be certified by the GBI rating system, the GEO Building had been installed with most advance innovation such as the spectrally selective double-glazing windows and BIPV panels. Yet by having the innovative atrium design, the LEO Building has a better natural ventilation system than the other, which comforts the occupants physiologically and psychologically.

Overall, the daylight design of the GEO Building surpasses other buildings. The energy consumption of lighting system in the GEO Building is obviously smaller than the other buildings. This indicates that the integration of mirror light shelf, roof light, reflective ceiling, and skylight system was a success, whereby the system promotes day light throughout the building and then lower the requirement of artificial lighting.

Both of the buildings also emphasized on the building orientation and interior space layout design in order to reduce the cooling load and artificial lighting system that require more energy. Though the LEO Building is having the site limitation, the architects tried their best to orientate the building envelope. The interior space layout design helps reduce the energy consumption by promoting day lit into the buildings.

Against these findings, it is ascertain that each of the features could not make a big difference in achieving Energy Efficiency, but to integrate all them into one whole Green Building Design. It is undeniable that this integration showcases the success of Green Building Design through the readings of Table 5.

Table 5 exhibits the comparison of monitored Building Energy Index (BEI) among the conventional government office building with GEO Building and LEO Building. By utilizing the Green Building Design approach, the LEO Building reduces the energy consumption down to
50% from the typical conventional buildings. On the other hand, the GEO Building surpasses all of the buildings by reducing the energy consumption down to 30%.

Table 5: Comparison of monitored BEI among conventional government office building, GEO Building and LEO Building

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Conventional Government Office Building</th>
<th>GEO Building</th>
<th>LEO Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitored Building Energy Index (kWh/m²/year)</td>
<td>200 - 300</td>
<td>65 (excl. PV generation)</td>
<td>114</td>
</tr>
</tbody>
</table>

4.0 Conclusion

Based on the two subjects in the case study chapter, it can be concluded that the Green Building Design that can be realized, and proved effective, in a Green Building and EE Building were the building orientation; shading devices; roof and walls insulation; daylight design; ventilation system; and interior space layout design. However, these features will not give a significant effect, but incorporate all of them together into one building’s design.

The paper reveals the efficacy of Green Building Design in context of Energy Efficiency. Compare to the BEI of the conventional government office building, which is 200 – 300 kWh/m²/year, the LEO Building is 114 kWh/m²/year and GEO Building is 65 kWh/m²/year. This is a thrilling result that serves to motivate all the building industry players to involve themselves in building green and sustainability.

5.0 Recommendation

As school is a prior asset to deliver the best education system, it is strongly recommend having a future research on having Green School Building Standard. Study from the two subject buildings in the previous discussion shown that Green Building Design has a short payback period such as 10 years compare to the age of building up to 100 years. Therefore, the government needs to change their mindset to get prepared for the emergence of Green School Building and alleviate the development of green environment. Early formal education can only be obtained from school. It shows how important schools need to be maintained in an energy efficient approach as well as to prolong their life-cycle.

McDonald’s (2005:57) concluded that “Despite the commitment of the private sector to sustainable development, it is clear that it is unlikely to be delivered without a partnership with government and the support of an appropriate fiscal and regulatory framework”. Hence, the public sector policy makers play an important part in realizing the vision of sustainability and green.
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