# MODELING OF BUILDING ENERGY EFFICIENCY BASED ON GREEN RATING SYSTEMS IN SUBTROPICAL CLIMATE.

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**Abstract -** In the recent years, sustainable buildings are highly focused. Especially the initial decisions during the design and preconstruction stages be requested as soon as possible. Thus the prediction of energy consumption in buildings is in demanding. This research work is aim to analysis the efficacy of building materials and building orientation based on energy use evaluation in subtropical climates. This research modeled the performance of efficient strategy on the similar non-residential buildings, located in the climate of Taiwan. In order to clarify the essential concern in building design in subtropics with warm-humid zones, rainfall and high humidity, alternative version has been simulated with same building located in different subtropics country, Vietnam. For comparison, baseline building is constructed from reinforced concrete, steel, cement, etc. Improved version of same building with efficient material and modified orientation they are Re-material and Re-orientation models. The energy use of the buildings were simulated by using Revit software and found that efficient modeling can save from 7% to 15% energy using. Cooling load plays a more vital part in Vietnam, whereas heating load is a bit more concerned in Taiwan. Each model located in Taiwan needs to be enhance 2.8 times their efficiency to achieve the same performance level of green building rating system in Vietnam based on two evaluation criteria: Taiwan- EEWH (Ecological/Energy saving/Waste reduction/Health) and Vietnam- LOTUS.

**Index Terms -** Energy efficiency, green rating system, simulation modeling, subtropical climate

## I. INTRODUCTION

Scientists from the Intergovernmental Panel on Climate Change (IPCC) carrying out global warming research have recently predicted that average global temperatures could increase between 1.4 and 5.8 °C by the year 2100 [1]. There are 50-60% global resources are consumed by buildings [2]. The Earth has risen between 0.4 and 0.8 °C over the past 100 years. Currently, many buildings are built without calculating long-term energy efficiency, in long-term will result in negative impacts on the environment.
Roberto Ruiz has presented analysis and evaluation methods to indicate the most important aspect influencing the final energy consumption in office buildings [3]. Abul Abdullah, 2014 also questioned the difference between simulation and actual in building energy consumption [4]. The reason is mostly due to the inabilities of the software to take into account advanced lighting and HVAC system and differ into the modeled results. The key research end-uses include heating, ventilation and air-conditioning (HVAC) system, domestic hot water, lighting, plug-loads, elevators, kitchen equipment, ancillary equipment and appliances [5]. Building Information Modeling (BIM) has become an irresistible trend in the development of construction industry in Taiwan. However, there are lacking of government-led integration and guidance forces and many countries seem to face similar problems. This study help to bring a method of civil technology on energy using evaluation aspects and try to simplify providing an estimation in initial decisions during the design and preconstruction stages. Taiwan-EEWH and USGBC-LEED Green Building Rating System had been compared and found it is not easy to know directly and clearly the strengths and weaknesses of the design case because of the distinct climate factors [6]. This study will aim to elucidate the energy efficiency used in buildings based on the similarity foundation between the two rating systems of subtropics. The dominated change of materials and building orientation as a positive way relying on software modeling. The energy use typically in subtropical climates in Taiwan and Vietnam will be clarified relied on comparative simulation results. Finally, those evaluations will initially suggest the possibility of effective strategies to gain points for both EEWH and LOTUS green building rating systems.

### A. Taiwan Green building rating system EEWH

To differentiate the level of "greenness" and encourage higher standards, the ABRI (Architecture and Building Research Institute, Ministry of the Interior) commissioned the research laboratory led by Lin Hsien-Te, professor at the Graduate institute of Architecture, National Cheng Kung University to establish a new grading system [7]. EEWH system has been well developed, simplified and modified for the subtropical climate of Taiwan and was regarded as a standard evaluation method for green buildings by the Ministry of the Interior of Taiwan [8]. There are now nine weighted and accumulative indicators, each with a different high and low scoring range, totaling 100 maximum points (continuous and including decimal points) shown in Table 1 and yielding five grade

levels: Diamond, Gold, Silver, Bronze and Qualified.

**B. Vietnam Green building rating system VGBC-LOTUS**

LOTUS Rating Tools share the same goal with existing international green building rating systems (LEED, Green Star, BREEAM, GBI, Green Mark, Greenship, etc.) and aim at establishing standards and benchmarks to guide the local construction industry towards more efficient use of natural resources and more environmentally friendly practices. The first certification level for LOTUS NR V2.0 has been benchmarked at 40% (LOTUS Certified) of the total amount of points [9]. This value reflects a good first level of performance and the minimum required for certification

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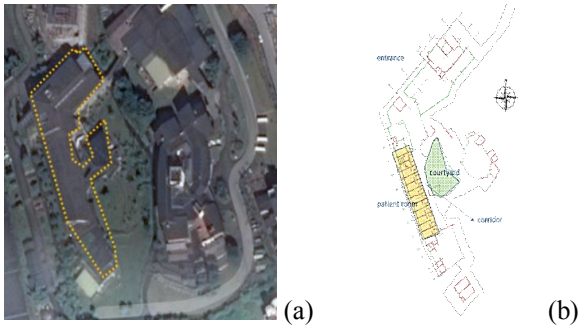
| EEWH Certification Level | Point | LOTUS Certification Level | Point |
|---|---|---|---|
| Qualified | 30% | LOTUS Certified | 40% |
| Bronze | 30-60% | LOTUS Silver | 55% |
| Silver | 60-80% | LOTUS Gold | 65% |
| Gold | 80-95% | LOTUS Platinum | 75% |
| Diamond | >95% | | |

**Table 1. EEWH & LOTUS certification system, performance levels**

## II. SIMULATION MODELING

**A. Project details**

St. Camillus Care Center was built in 2005 at 101 號, Sec. 2, Sanxing Rd, Sanxing Township, Yilan County, Taiwan (Fig. 1). Geographical coordinates: 24°40'03.8"N, 121°42'22.6"E.




(a) (b)

**Figure 1. Project details. (a) Project location. (b) Project floor plan in model**

Yilan area is between subtropical and temperate temperatures, the annual average temperature is 22.3 ℃, summer more than 28 ℃; which in July was above the highest 28.8 ℃, very warm climate of the region. Relative humidity of the region's annual average of 78.2 % in the spring, the highest of 81.3% in March, the lowest 73.4 in Dec. In the past 10 years the region's average annual rainfall is 1298.8 mm rainfall concentrated in summer and spring. Climate data is collected from central weather Bureau [11].

Health care center 2006 Yi-Lan County achieved excellent green architecture design award [10]. The most important design strategy is the roof system conducted with large overhang. There are structural walls located in important positions of the building center. Glass-system is used in majority for window and exterior façade to welcome the natural light into the building. However, there are some doubts about design intentions such as: Patient rooms are located on the west. Glass system for exterior wall is needed for patients to contact with nature views but must be always covered by shading system.



**Figure 2. St. Camillus long-term Care Center model**

**B. Simulation method**

**1. Baseline model**

Modeling of St. Camillus long-term Care Center is built up based on the technique of Revit tools with Healthcare building type setting. The location is defined by internet mapping service at weather station code: 549317. Export category is analysis for rooms. Analytical space and surface resolution are 457 and 304 respectively. The baseline modeling is indicated by the following materials: Lightweight construction with typical mild climate insulation is assigned to mass exterior wall and mass floor, while interior walls are without insulation. Mass roof is structured by typical insulation with cool roof. The system of glazing and skylight are constructed by double pane clear without coating.

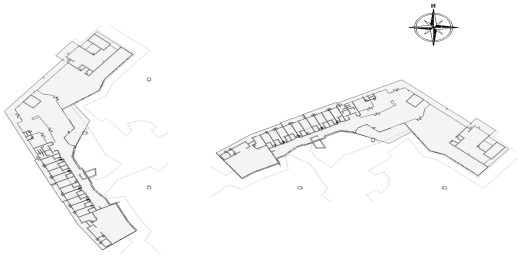
**2. Re-material model**

Re-material model is express as similar as baseline about the building type, location spaces and climate condition. However, mass models are constructed by more efficient material. Mass exterior wall and mass floor is conducted by lightweight construction with high insulation instead of typical mild climate insulation. Besides, high insulation material also set for roof, floor system. Air and shade are remain as same with the baseline while mass glazing and

skylight are replaced with high performance, LowE, high Tvis, Low SHGC.

### 3. Re-orientation model

Re-orientation model is interpreted as similar as Re-material about the building type, location spaces, climate condition and effective material replacing. However, the actual direction of the building is considered as disadvantageous. The direction of the patient's room and the main side of building is in the west (Fig. 3a), which is essentially ineffective and even harmful in the long term economically or energy use. So we decided to change the building orientation of the project in the most beneficial way as shown in Fig. 3b.



**(a)** **(b)**

**Figure 3. Simulation model. (a) Origional model. (b) Re-orientation**

## III. RESULTS COMPARISON AND DISCUSSION

For energy analysis we have been chosen two different type of alternative models: Re-material and re-orientation modeling. Here we have considered the monthly whole- Energy Use Intensity, Annual Energy Use/Cost, Energy Use: Electricity, Monthly Fuel Consumption, Monthly Electricity Consumption, and Monthly heating-cooling Peak Demand for comparison among these materials.

### A. Comparison between Baseline model, Re-material and Re-orientation models

### 1. Energy use intensity

Energy use intensity is annual building energy use kWh divided by building area $m^2$ and described the intensity per square meter in a year. Table 2 shows the difference in energy use intensity (fuel, electricity and total EUI) between baseline model and Re-material model and Re-orientation as 944, 879 and 853 MJ/m2/year respectively. The reduction value for every improvement is 7% for Re-material and 10% Re-orientation model.

| Units | Baseline | Re-material | Re-orientation |
|---|---|---|---|
| Electricity EUI *(kWh/m2/year)* | 240 | 229 | 221 |
| Fuel EUI *(MJ/m2/year)* | 82 | 55 | 56 |
| Total EUI *(MJ/m2/year)* | 944 | 879 | 853 |
| **Reduction** | **0%** | **7%** | **10%** |

**Table 2. Comparison of Baseline, Re-material and Re-orientation modeling of energy in intensity**

### 2. Annual Energy Use/ Cost

Annual energy use of each typology of building and its annually electricity cost and fuel cost is given in Figure 4. The annual energy use reduced significantly by changing the material and orientation. They are 65589$, 61473$ and 56544$ for baseline, re-material and re-orientation respectively. Re-material can reduce 6% the energy cost and this of Re-orientation is 14% compared with baseline model.

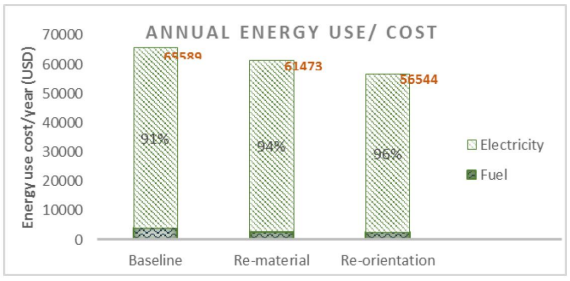



**Figure 4. Comparison of annual energy use/cost of Baseline, Re-material and Re-orientation models**

The usage of fuel demonstrated a vital reduction in different models. This feature needs for baseline is 4064$ and lower as 2702$ and 2571$ for Re-material and re-orientation respectively (Fig. 5).

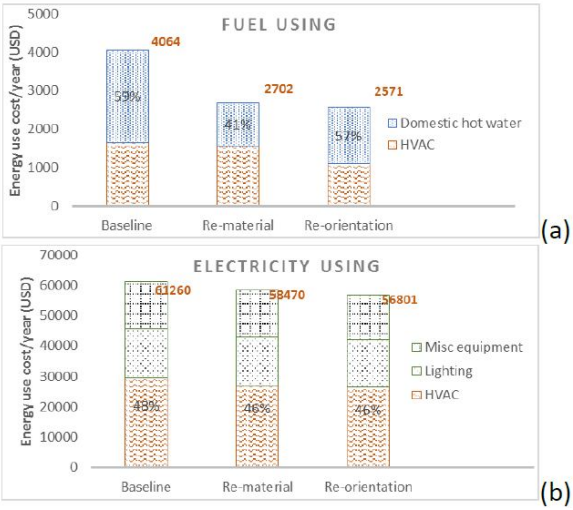



**Figure 5. Comparison of Baseline, Re-material and Re-orientation model. (a) Fuel using. (b) Electricity using.**

The Re-material model represented a reduction of 34% and re-orientation shows 37% reduction comparing with the baseline model shown in Fig. 5a. The vital decrease is took part on HVAC for Re-orientation model, this mean the changing of building direction to suitable way can significantly helpful in fuel using of HVAC. On the other hand, electricity usage in Re-orientation shows a reduction compared with Baseline model from 61260$ to 56801$ those values are shown in Fig. 5b. The reduction of electricity energy using in this section is presented 5% to 7% by re-material and re-orientation model.

### 3. Monthly Electricity Consumption

When the project uses fuel for heating (as opposed to electric heating sources), fuel usage increases during the colder months of the year. During winter consumption is lower. The cooling load is more emphasize for subtropics demanding whereas the cooling load accounts for a small portion.

#### i. Monthly heating load

Monthly heating load section simulates the thermal energy needed to satisfy the building for heating purposes. Those purposes are indicated mainly in Misc equipment, lighting fixtures, occupants, window conductive, walls, etc. Noticeably, Taiwan is a typical subtropical climate, thus, heating load is high demand in the winter season from Dec to Mar and this features are drop to zero in summer from Apr to Nov (Fig. 6).

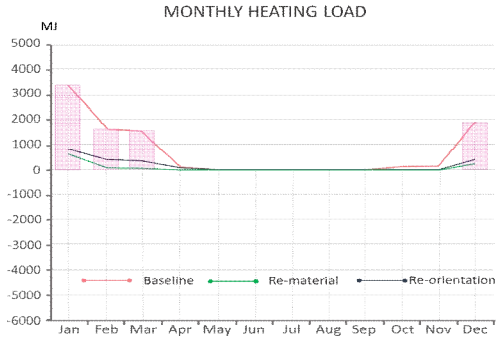



**Figure 6. Comparison of monthly heating load of Baseline, Re-material and Re-orientation model**

Heating load needed for the winter in Baseline shows more than 3000MJ in Jan and around 1500MJ in Dec, Feb and Mar, whereas this feature demands lower value for same period in Re-material model as lower than 500MJ and a negligible difference for Re-orientation. In another words, the Re-material and Re-orientation model can reduce 74% heating load of Baseline.

#### ii. Monthly heating load

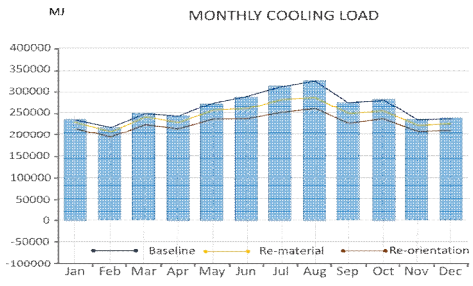



**Figure 7. Comparison of monthly cooling load of Baseline, Re-material and Re-orientation models**

The typical subtropical climate most clearly expressed in monthly cooling load Fig. 7. The total cooling load demanding for Baseline model presented a higher intensity than the alternative versions and are computed at around 250000MJ in Jan to Apr, Nov and Dec. This feature then reached to the peak in Jul and Aug until 330000MJ. Whereas, Re-material and Re-orientation kept the lower level around 220000MJ and 200000MJ.

The monthly heating load and cooling load then synthesized in Fig. 8. Re-orientation represents a least energy demanding. Re-material model located almost in the mean position between the baseline and re-orientation. Changing the direction of the building is of equal importance to the optimal material change for the building. In other words, although the strategic of direction is easy, it also contribute an initial decisive strategy in the efficiency of energy using.

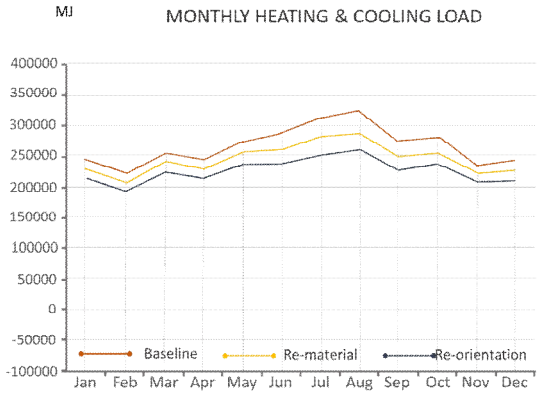



**Figure 8. Comparison of Baseline, Re-material and Re-orientation modeling of monthly heating and cooling load**

Noticeably, the deviation between the efficient models and the Baseline during winter months seem to be evenly spaced, meanwhile, effective models indicates a relatively bigger deviation in the summer months. This indicates the effectiveness of the strategy applying to the building in the summer of subtropics.

### B. Comparison between model in Taiwan and Vietnam

#### 1. Energy use intensity

Energy use intensity of Re-orientation model assumed in subtropical climate of Vietnam as 944, 983 and 853 MJ/m2/year respectively (Table 3). The reduction value for final improvement is 15% compared with baseline model in Vietnam. This shows a potential in earning credit in LOTUS system that will be discussed in next section.

| Units | Taiwan | Vietnam | Re-orientation |
|---|---|---|---|
| Electricity EUI *(kWh/m2/year)* | 240 | 265 | 221 |
| Fuel EUI *(MJ/m2/year)* | 82 | 28 | 56 |
| Total EUI *(MJ/m2/year)* | 944 | 998 | 853 |
| **Reduction** | **--** | **0%** | **15%** |

**Table 3. Comparison of energy in intensity in Taiwan & Vietnam**

#### 3. Monthly heating load and monthly cooling load

The demanding for heating load results in a very low value compared with Taiwan model. Thus, in the

subtropical climate as Vietnam, monthly heating load is negligible even in winter. This demonstrates a very adaptable building model for Vietnam in winter. The peak of heating load in Jan is only 7MJ, whereas this feature of Taiwan is more than 3000MJ.

Together with the energy use intensity in Table 3, Fig 9 performed a similar trend in cooling load demand that baseline model in Vietnam shows a higher average energy use than Taiwan model. The use of the same baseline model in Vietnam is less effective than in Taiwan. Obviously, the peak demand and average consumption in Vietnam are always higher.

The highest demand for cooling load is separated from Apr to Sept. this peak demand is approximately 350000MJ for Vietnam and 300000MJ for Taiwan. The deviation gap between the two locations are around 20000MJ to 50000MJ, which is small in winter and bigger in summer.

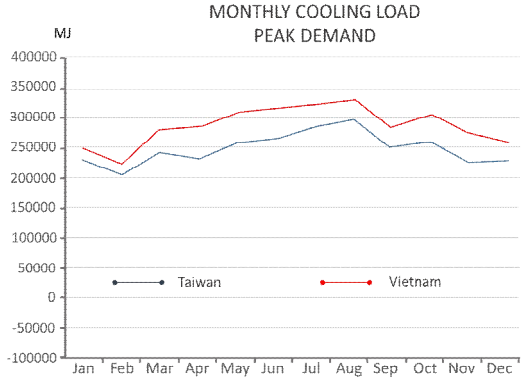



**Figure 9. Comparison of monthly heating and cooling load in Vietnam and Taiwan**

### C. The effect of subtropical climates on the design strategy

The temperature chart shows a relative difference between the two countries (Fig. 10a, b). The temperature in Vietnam seems higher than in Taiwan, so Vietnam gets a warmer winter and hotter summer. The chart also presents the winter in Vietnam is likely more comfortable, while temperature deviations in Taiwan almost larger than Vietnam. Comparing the temperature line and cooling load demand seems incompatible, especially in Taiwan. The temperature peaks in Taiwan are quite high during the summer months, while the cooling requirement for the building is not follow. This explains the characteristics of the typical subtropical climate and, this, significant affected by the relative humidity (Fig. 10). The relative humidity in two countries are quite high.

Concerning about thermal comfort in both countries, the design strategy to ensure energy savings is quite similar. However, the small details are still differences and interesting. According to Climate consultant (computer software), The Psychrometric Chart (Fig. 10) shown to the left is one of the more advanced features available in Climate Consultant. Each dot on the chart represents the temperature and humidity of each of the 8760 hours per year. Fig. 11(b) shows a denser comfort points than Fig. 11(a) and also a larger area as well.

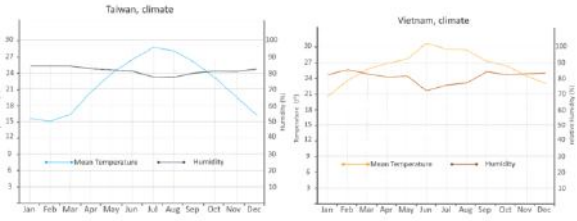



**Figure 10. Temperature and humidity. (a) Taiwan. (b) Vietnam**

The thermal comfort zone in Vietnam required a higher contribute of cooling load as 57% compared with 48% that of demanding in Taiwan. Whereas, the heating load needed in Taiwan is 1.2 times that of Vietnam. In the other words, Vietnam's design campaign needs more attention on cooling load than in Taiwan. This means the Baseline model still needed to add more cooling strategy rather than envelops and materials to satisfy the warmer climate.

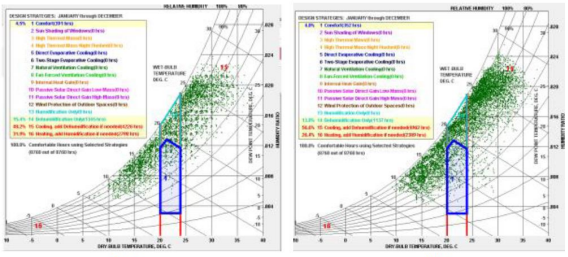



**Figure 11. Thermal comfort zones. (a) Taiwan. (b) Vietnam**

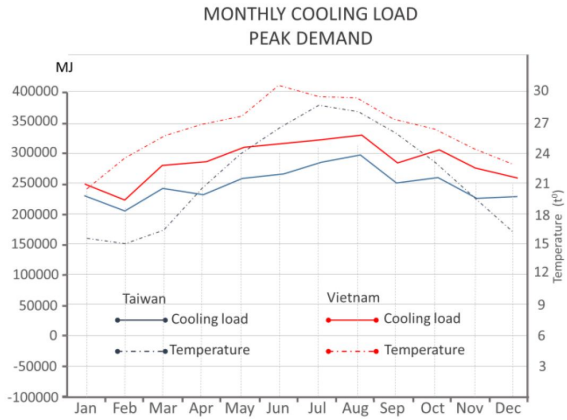



**Figure 12. Temperature and cooling load of Taiwan and Vietnam**

However, the humidity of Vietnam is generally lower, and this humidity is lower in summer to around 70%. This is one of the fundamental reasons why Vietnam's temperature and demand load curve are relatively matched. On the other hand, it also emphasizes that

the design strategy for buildings in the climate zone is not simply based on temperature, humidity plays a dominant role in this design strategy.

Although Fig. 12 shows that Vietnam's cooling heat load demands higher in Taiwan, however, the same design strategy, building located in Vietnam is more effective than in Taiwan within 5% of energy saving. This figure, together with the thermal comfort charts of the two countries also show that the design strategy for each climate region is different even they are both subtropics and that the design strategy for a Taiwanese project should be more focused. Furthermore, the same project if located in Taiwan would be not as effective as in Vietnam, and hence the design and analysis as well as are required to be more attention.

## IV. DISCUSSION ABOUT ACHIEVING POINT WITH RESPECT TO RATING SYSTEM VIETNAM AND TAIWAN CODE

### A. Achieving points under EEWH and LOTUS codes

Daily Energy Savings indicator is divided into three categories, Building Envelope, AC System and Lighting System. The building envelope must satisfy all of sub-criteria A, B and C to pass. They are: A. Glare control of glass surfaces; B. Shading requirements for horizontal glazing; C. All building types must outperform by 20% the envelope requirements of current building energy codes and D. Insulation requirements for buildings at high elevations. Within the article's scope, we focus only the Building Envelope section (only sub-criteria C is evaluated), AC system and Lighting System are out of this cope in order to settle a fair comparison with LOTUS rating system.

All building types must outperform by 20% the envelope requirements of current building energy codes:

$$EEV = EV/EVc \leqq EEV\ c = 0.8 \quad (1)$$

Where: EEV, EEVc: Energy efficiency of the building envelope and corresponding benchmark value (no unit for both) EV, EVc: Energy consumption indicator of building envelope and corresponding benchmark value. Energy section accounts for 28% of total nine sections of LOTUS non-residential weighting. Similarly with EEWH, we chose one defined criteria that would be clearly relevant to the scope of this study. Table 4 shows the total building energy use, this indicator is one of 7 categories of LOTUS Energy requirement sections.

| Total building energy use | 14 point |
|---|---|
| Project complies with all mandatory requirements of VBEEC | Prerequisite |
| Demonstrate 10% reduction of the total building energy use compared to Baseline Energy | Prerequisite |
| 1 point for every additional 2.5 % reduction of energy use from the baseline (Up to 45%) | 14 |

**Table 4. LOTUS Energy consumption code**

### B. Evaluation achievement levels by EEWH and LOTUS codes

According to Table 2, the simulation results in Re-material and Re-orientation show the ratio EV/EVc as 0.93 and 0.9. Both are higher than 0.8 (shown in Eq 1), so by efforts to change the envelope in to efficient materials, the building performance (from 7% to 10%) is still be hide the requirements of energy codes within 20% outperform. Unlike EEWH system, LOTUS has potential in getting point by demonstrate 10% reduction of the total building energy use compared to Baseline Energy. Following this code, the Re-material model is only eligible to achieve the prerequisite with 10% reduction. To get the point, the building must perform 2.5% additional reduction of energy use. Obviously, the Re-orientation model conducted with 15% energy reducing compared with baseline, it means this version get totally 5% additional decreases so, in final, the model can gain 2 points in this credit of LOTUS system. In order to assess the satisfactory level of the models based on two green rating systems, the energy use section was divided into 3 stages, they are 1. Unsatisfactory zone, 2. Prerequisite threshold and 3 (Fig. 13). Credit zone. For EEWH, both alternative versions of Re-material and Re-orientation are judged as below the prerequisite. Re-orientation model is closer to prerequisite threshold than re-material model as the coefficient respectively negative of 0.5 and 0.65 from the prerequisite line.

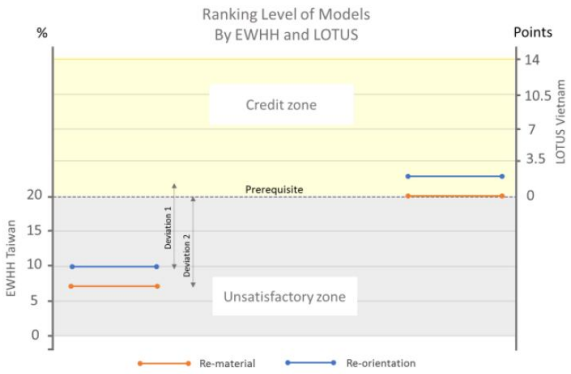



**Figure 13. Assessment levels based on EEWH and LOTUS**

In simple terms, Re-orientation has to double its efficiency and Re-material is further of this number to adapt the prerequisite of Taiwan. Whereas, rating by LOTUS, Re-material can achieve the prerequisite and Re-orientation, moreover, can reach to higher credit zone. It is assumed that 2 points per total 14 points accounts more than 14% of this zone. The Deviation 1 and Deviation 2 shows the challenge between two rating systems. This gap can simplify the distance how far a model can be improved to meet their requirement. Each model in Taiwan should improve 2.8 times of their performance to reach the same level in Vietnam. Interestingly, the deviation between

Re-material and Re-orientation shows the same value in two systems. Importantly, those deviations indicated that the two rating systems even have different degrees of rigidity, but their performance is almost equal. In other words, if the building has same strategy of improvement, they can earn the same percentage of success target. This may be in part to assess the level of reliability of these systems in the future.

## CONCLUSION

By the help of BIM, the efficiency of energy using is clarified. Re-material model with changing of high insulation to walls, floors, roof mass and high performance, LowE, high Tvis, Low SHGC of glazing system can safe until 7% of energy consumption and Re-orientation model can reach to 10% of this feature. The simple strategy at early decision on building like orientation is very cheap and easy but seriously take in charge of building energy efficacy. In subtropical climates, the cooling load is key point for design strategy compared with heating load. The strategy is not only based on the high temperature of those climate, they should consider the effect of humidity and thermal comfort of each zone. For the countries that have a wider range of thermal comfort zone like Vietnam that can easier to success in archiving a better design project. The simulation shows 5% more effectiveness that can gain if applying same strategy to Vietnam than Taiwan. EEWH system in Taiwan shows a higher demanding of achieving points in energy section. The ratio between energy consumption indicator of building envelope and corresponding benchmark value of simulation models are always higher than threshold 0.8. Whereas, it is easier to collect 2 points as same section of Vietnam green building system using similar design strategy with 15% energy reducing improvement. Based on the scope of energy consumption, this study has established a compatible scale for both countries, and head designers to pursue the antecedent strategies in gaining higher points. Future studies should consider a wider scope together with lighting features and lifecycle assessment to get more details in their design strategy.

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