The Ecological Building Assessment Index for Hot Humid Region

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Abstract

Since the energy crisis became the global issue, most buildings including designers have faced to the energy conservation and global warming concern. Many assessment indices were developed in countries such as BREEAM in United Kingdom, CASBEE in Japan, GREEN MARK in Singapore, Green Star in Australia, and LEED in The United States of America. It is found that each assessment index has designed to support its country, especially for government policy as criteria of environment, energy, culture, technology, and natural resource concerns. However, all assessment indices would perfectly fit only to specific region, climate, and policy. BREEAM, for instance, emphasis on environment loading such as CO_2 emission, water consumption, energy consumption, and less impact on transportation, while CASBEE concerns on energy management, materials, site pollution, and also less impact on transportation. Therefore, building in Japan will not get the good score by using BREEAM or others. BREEAM and LEED concern CO_2 emission because of UV problems. The recommended appropriate assessment index for hot-humid region should consist of government policy, environment, local climate, and available technology. Energy consumption would be a major concern for environmental impacts and reduce nonrenewable energy such as imported fossil fuel. Designers must beware of humidity factor along with cooling design. By using Ecological Building Assessment will lead designers to propose good buildings fit to the region character.

Keywords Ecological Building Assessment Index, CO_2 Emission, Global Warming

1. Introduction

The idea of ecological design concept does not aim to reduce energy problem. Rather, it is the design that harmonizes architecture and environment that can help reducing environmental problems. Such problems include greenhouse effect and urban heat island that lead to climate change. The issue of environmental impact and climate change brings immediate attention to environmental and energy conservation in the residential sector.

In addition to the enforcement of energy regulation for large buildings, information of case studies also shown that the Royal Thai Government has encouraged the ecological building assessment in residential sector since 2007. However, instead of applying building assessment developed in its own country, the use of building assessment indices that are developed in other countries is more commonly accepted. Thus, a question of choosing a suitable building assessment index for Thailand needs to be answered.

The purpose of this paper is to analyze influential factors on building design in the hot humid region that not only can decrease environmental impact and achieve lower energy consumption, but also promote a higher level of living quality. The result of this paper can be used for the development of building assessment index that truly responds climate characteristics of this region.

2. A Concept of Ecological Design in Hot Humid Region

Hot and humidity for all year is a distinct climate characteristics of the hot humid region, which cause a high indoor temperature beyond comfort level. Cooling load of building requires up to 70 per cent of total energy consumption. Compare with 15 per cent required for electricity, cooling loads account for the majority of energy and natural resource consumption. [1] Influential factors in building design that respond to climate conditions are essential to establish criteria for the assessment of buildings in this region. The study on the development of ecological building assessment in hot humid region focuses on the following objectives:

1. examine the result of various international assessment methods on a well known building in ecological design
2. develop an approach on ecological building assessment index that based on local context in a preliminary design stage

3. Methodology

3.1 Characteristic of the Climate

This research selects building assessment methods from different climates. As the climate is a major factor that influence building design both on basic requirement in comfort condition and energy conservation, this study applies Koppen and Geiger (1936 cited in Olgyay, 1992: 6) for criteria in the evaluation. Köppen- Geiger climate classification is based on characteristics of the climates and vegetation in five regions that are tropical, arid, temperate, cold and polar climates.

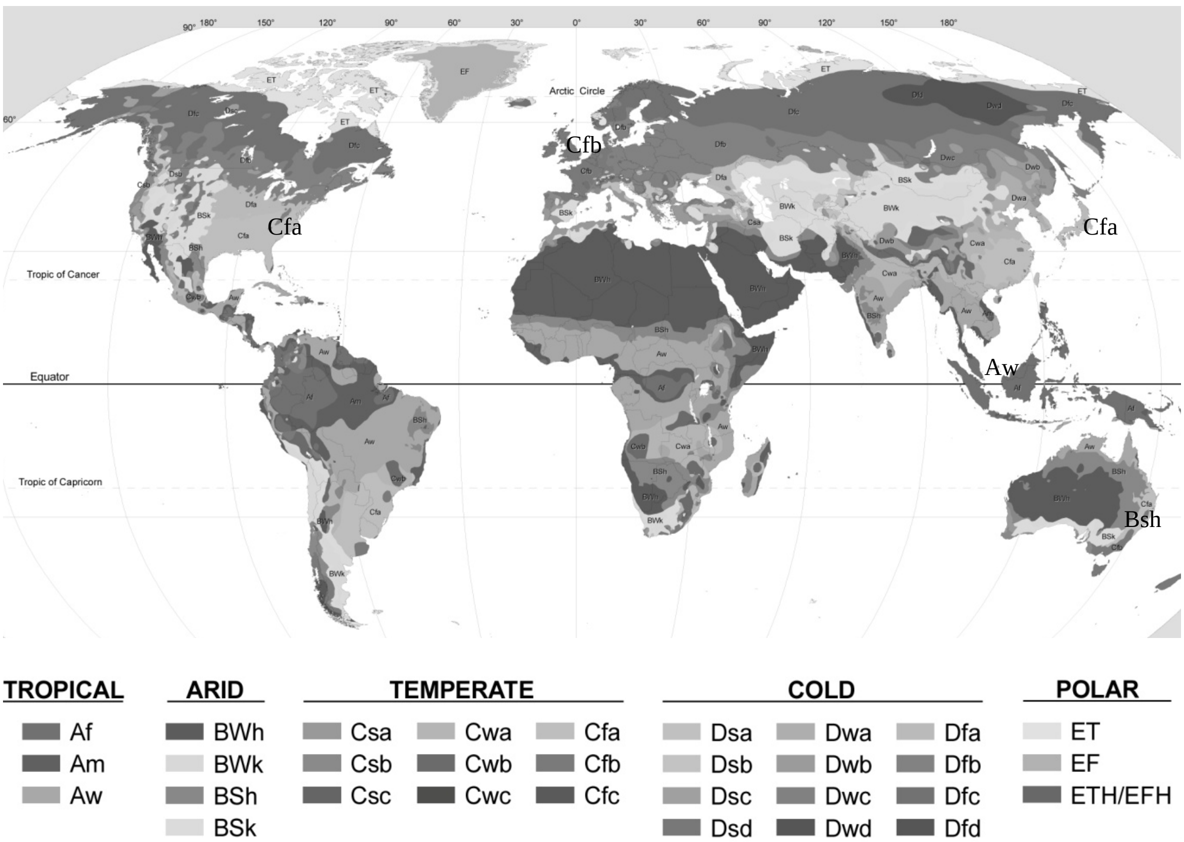


Fig 1. World map of Köppen- Geiger climate classification

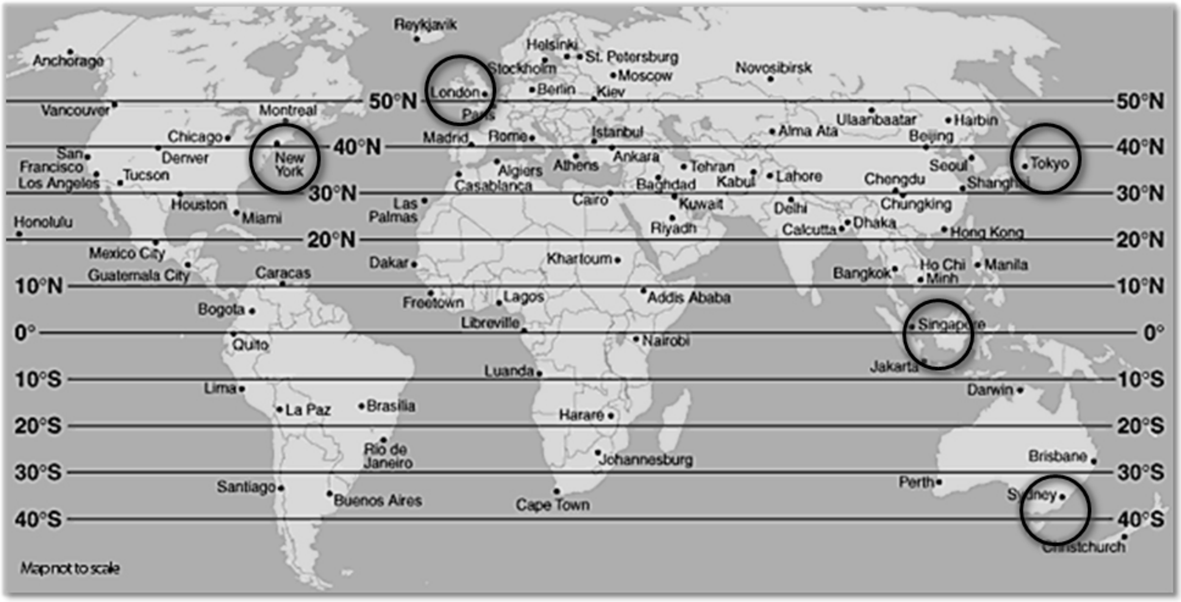


Fig 2. World map describes origin of building assessment tools in various countries

According to the continental and polar climates that have not been set up the international assessment tools, this study then focuses on five countries in various climate regions. The study of these different tools clarifies influential factors. The result of the study is used as a prototype and reference information for the development of the ecological building assessment index for hot humid region. Building assessment tools in this research include:

Table 1 Origin of assessment tools with location and climate

Country (city)	Building assessment	Latitude /Longitude	Climate
Australia (Sydney)	Green Star	33.86°S /151.19°E	Arid Climate
Japan (Tokyo)	CASBEE	35.68°N /139.69°E	Temperate Climate
Singapore (Paya Lebar)	Green Mark	1.37°N/ 103.90°E	Tropical Climate
United Kingdom (London)	BREEAM	51.15°N /0.10°W	Temperate Climate
United States of America (New York Laguardia)	LEED	40.76°N /73.90°W	Temperate Climate

3.2 Review of Assessment Methods

BREEAM (United Kingdom) The Building Research Establishment Assessment Method is used for the evaluation of new and existing buildings in residential, commercial and industrial building type. This method considers scores in terms of energy, transportation, water and material that are rated on scale of pass, good, very good and excellent. [2]

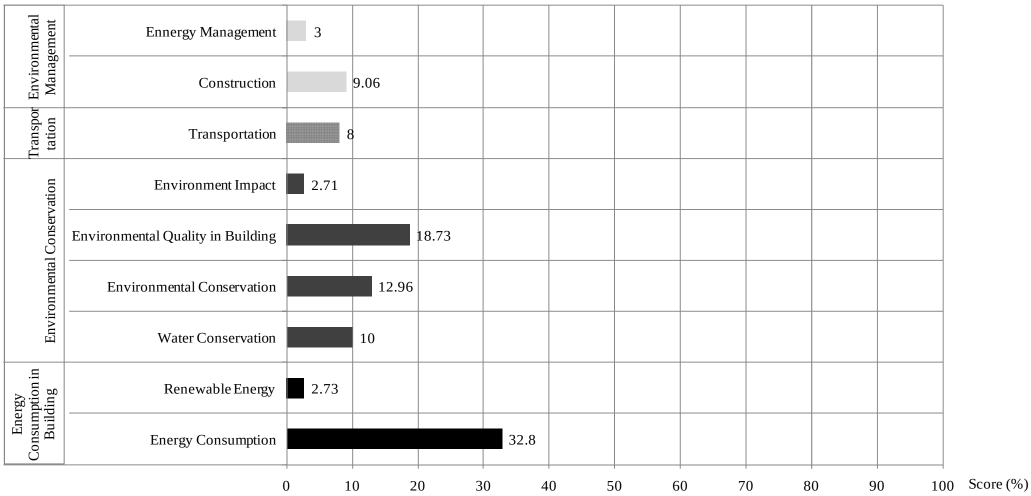


Fig 3. Demonstration of scores that are given in different criteria in BREEAM

CASBEE (Japan) Comprehensive Assessment System for Building Environment Efficiency (CASBEE) is used for the evaluation of buildings in terms of energy consumption and environmental load performance. The tool considers a balance in two categories: quality and loading. Quality category (Q) assesses living quality within building site boundary. Loading category (L) assesses environmental load beyond building site boundary. The total score is weighed by the Building Environment Efficiency (BEE) method and resulted in C, B-, B+, A and S scores. [3]

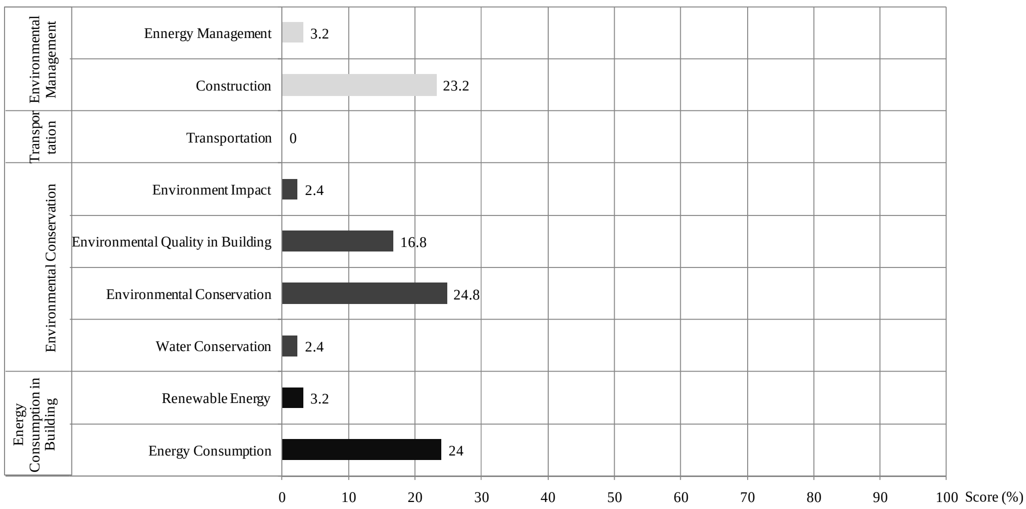


Fig 4. Demonstration of scores in each category in CASBEE

GREEN MARK (Singapore) is a rating system that aims to evaluate buildings in terms of environmental impact and performance. The system concerns five key criteria in: Energy Efficiency, Water Efficiency, Site/Project Development & Management (Building Management & Operation for existing buildings), Good Indoor Environmental Quality & Environmental Protection and Innovation. The assessment is awarded in Platinum, GoldPLUS, Gold or Certified rating depending on scores. Not only achieving maximum scores in each rating scale, the building also has to meet all pre-requisite requirements with a minimum of 50 per cent scores in each category except for the Innovation category. [4]

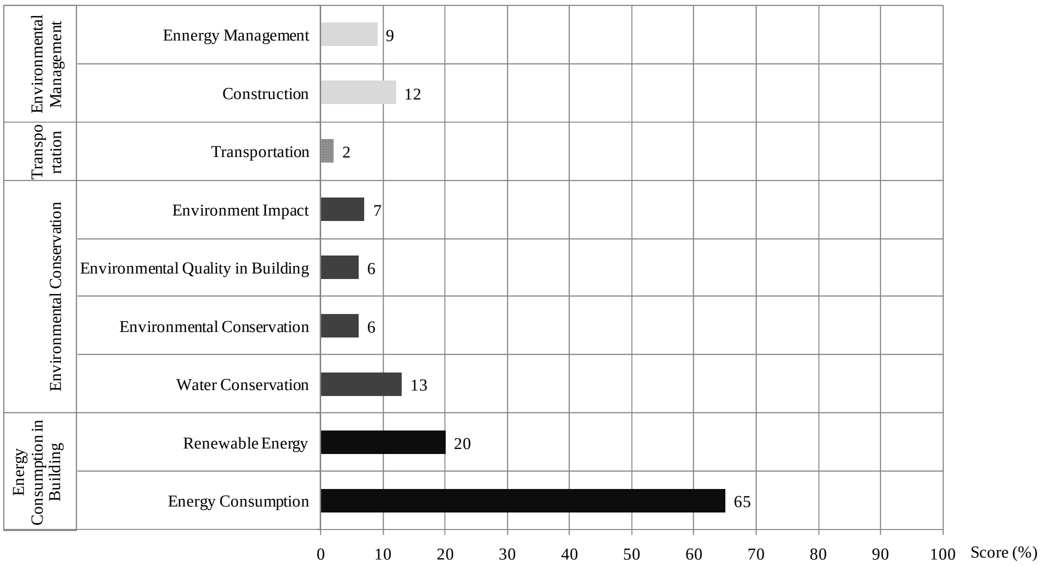


Fig 5. Demonstration of scores in each category of GREEN MARK assessment tool

Green Star (Australia) is used for prediction and measurement the environmental load of multi-unit residential, commercial office and the existing building. Green Star assesses energy and water consumption, number of resident and appliance, material and reused land. Environmental load is concerned in thermal comfort, indoor air quality and emission. [5]

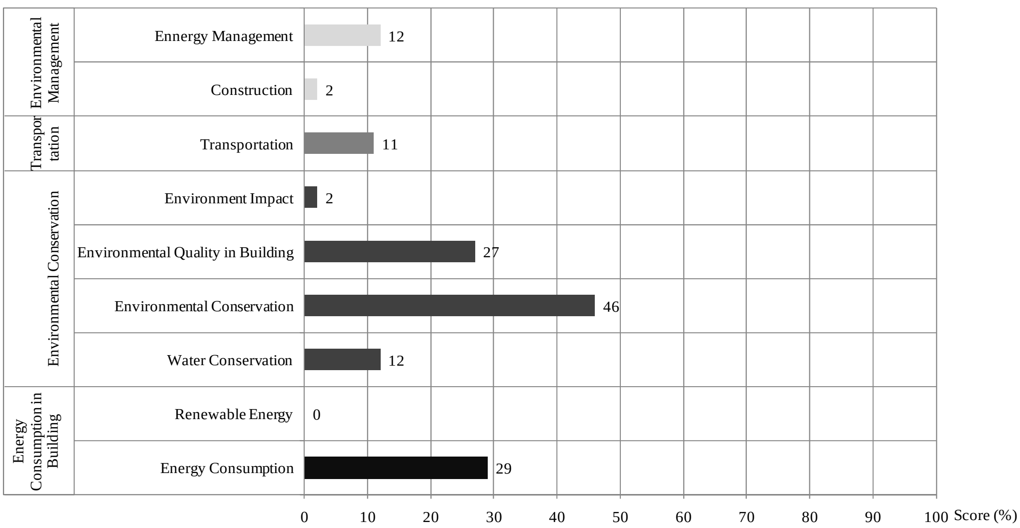


Fig 6. Demonstration of scores in each category of Green Star assessment tool

LEED (United States of America) Leadership in Energy and Environment Design (LEED) assesses scores in sustainable site development, water, energy, material selection and indoor environment. LEED is used for the evaluation of new construction, school, hospital, residential and existing building. Assessment is rated as Certificated, Silver, Gold and Platinum [6]

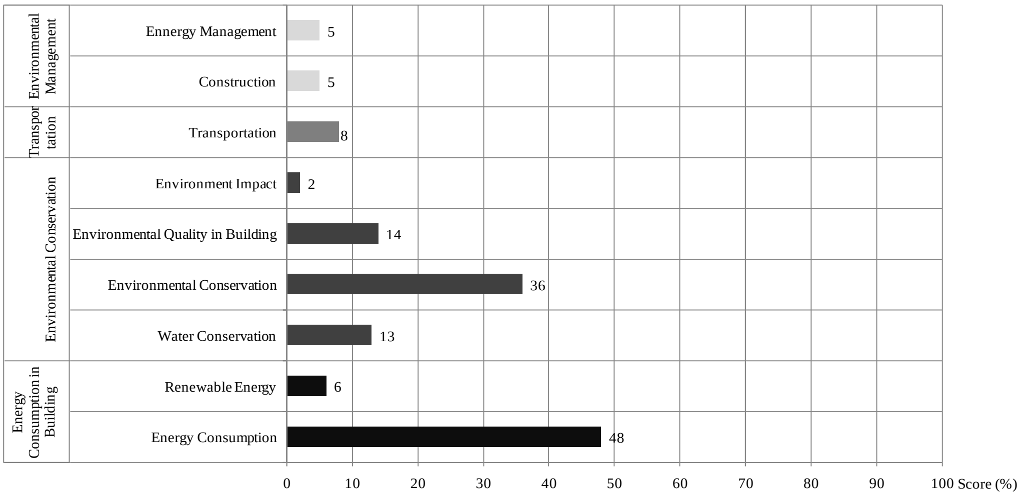


Fig 7. Demonstration of scores in each category in LEED

3.3 Human Comfort in Hot Humid Region

The climate in hot humid region causes in high temperature for almost the year. In 1998, climate information in Bangkok reported that there were only 645 from 8,760 hours in total hours of one year, which climate in external environment was in the comfort zone. The temperature in this comfort zone was 22-27 °C (71.6 – 80.6°F) and relative humidity between 20-75 per cent [7] or 7.36 per cent from total hours. While climate condition of external environment under comfort zone was below 22°C or only 85 per cent, there were up to 8,031 hours that temperature reached 27°C or 91.68 per cent. The information demonstrated that December was the month that has most hours in comfort condition, which account to 44.8 per cent or 14 hours. However, climate condition from April to October was not reached comfort zone level.

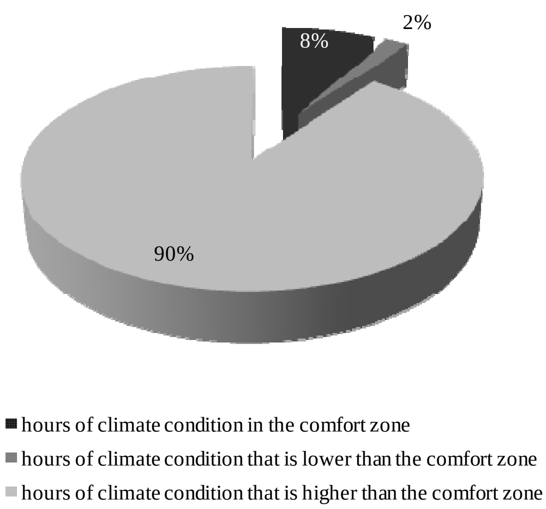


Fig 8. Percentage of hours in the comfort zone in one year

Table 2 Percentage of hours in one year that reach comfort zone within normal condition

Country (city)	Building assessment	Number of hours per year (%)		
		Climate hours in the comfort zone	Climate hours lower than the comfort zone	Climate hours higher than the comfort zone
Australia (Sydney)	Green Star	15	77	8
Japan (Tokyo)	CASBEE	5	81	14
Singapore (Paya Lebar)	Green Mark	1	0	99
United Kingdom (London)	BREEAM	3	96	1
United States of America (New York Laguardia)	LEED	11	75	14

The analysis of case studies in five countries finds that 93 per cent of hours in one year can not use external climate to create comfort condition in building, which result in the large amount of energy required for controlling the indoor climate.

Countries in temperate and dry climate have more hours of climate condition, which is lower than the comfort zone and cause the need of energy for heating load. On the other hand, in the month of July, the building requires for cooling load. In Singapore, where almost hours of the climate condition in one year are higher than the comfort zone, the requirement of energy for cooling load is necessary.

4. Result and analysis

The ecological building assessment should be considered in four dimensions that include policy, climate, technology and environment. Policy aspect introduces major source of energy and resource of the country, ongoing national strategic development plan and accessibility to environment loading. Climate aspect refers to factors in temperature, humidity and wind speed. Technology aspect includes the consideration of construction material, use of renewable energy in building. And environment aspect is considered in terms of environmental load and CO_2 emission.

This paper analyzes several building assessment methods in terms of climate and technology model aspect in order to create weighing factors for the development of the ecological building assessment index.

4.1 Case Study

A case study is selected for assessment in order to find main factors involved in the development of an ecological building assessment index. In addition, the relationship between related factors is essential to the design of the weighing system for this research and future study. The proposed case study is the Bio-Solar Home.

Assessment	Score
BREEAM	Good
CASBEE	Very Good
Green Mark	Green Mark Platinum
Green Star	Best Practice
LEED	Gold

Fig 9. Conclusion of the assessment of the Bio-Solar Home from various assessment methods

The Bio-Solar Home is a building that designed from the analysis of local climate, which combine materials suitable for the hot humid climate with building design concept. This building was designed to reduce energy consumption as well as the less impact to the environment. From the study of the Bio-Solar Home, it achieves the highest scores in Green Mark assessment tool, while it is only rated in good level scores in the other four assessment tools.

This research aims to find relationships between the main factors of people, building and environment, which can be analyzed to develop a more efficient building design in order to provide comfort conditions to the environment. This approach can be achieved by reducing energy consumption and environmental impact to the minimum. As a result, the case study is analyzed in details related to main factors in various assessment tools, which can be categorized as the following diagram.

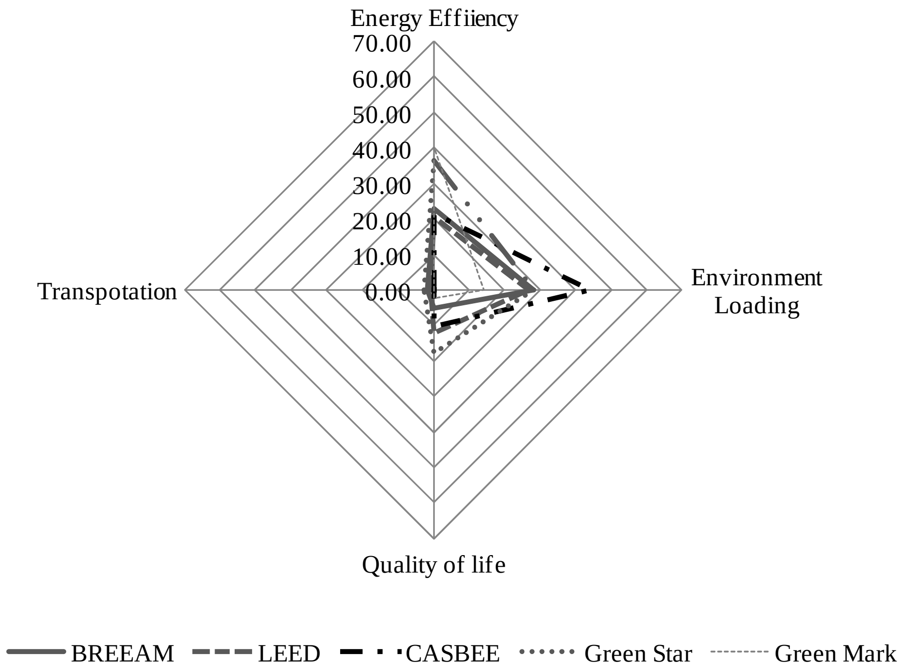


Fig 10. Demonstration of scores in the four influential factors of the Bio-Solar Home from various assessment tools

Criteria for building assessment are developed from policy, technology and energy conservation guidelines of the individual country that also respond to climate conditions and energy use pattern. The assessment of the Bio-Solar Home in various assessment methods results in differences of scores, and it cannot achieve high scores in some methods. Main factors that influence the development of an assessment tool can be described as:

1. Government Policy
    - Government policy in energy and resource utilization
    - Urban expansion and transportation
    - Building law, design regulation and construction standard

2. Climate condition
    - Pattern of energy use in building in individual country
    - The way to take advantage of nature to create comfort condition in building
    - Combination of design features to take advantage of the nature

3. Technology
    - Construction materials that respond to energy use pattern according to climate condition
    - Building equipment that achieve high efficiency and produce the less impact to the environment
    - Renewable resource

4. Environment
    - Environmental quality in building
    - Level of CO_2 emission to the environment
    - Amount of waste in building life cycle

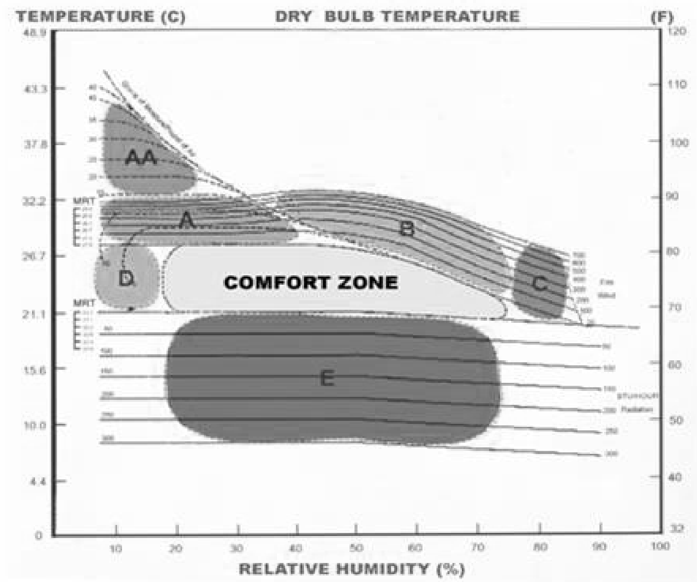
From the analysis of several assessment methods, the most influential factor that effect on the development of ecological building is the relationship between climate condition and building design. This relationship can bring a building to the highest potential in terms of the reduction of energy consumption, less environmental impact and still achieve living quality.

In conclusion, building assessment tools from various countries rely on different climate condition and energy use pattern of the individual country that bring about the differences of weighing scores in each category in regards to comfort condition. The evaluation of building assessment tools from other countries that based on data of each country can cause defective values from actual building efficiency. In another word, the development of assessment method in Thailand that based on assessment criteria from other countries may be necessary to use materials or technologies that do not respond local conditions, which may result in higher construction costs due to a different construction standard. Therefore, building assessment should be developed from actual data of the individual country in order to create an assessment tool that is suitable for the design of building in a particular environment.

4.2 The Application of Natural Factors in Building Design for Comfort Zone Modification

There are many natural factors in building design that help saving energy, increase quality of life and respond to human needs that include: [8]

- Site & Climate
- Building form & Building system
- Users and Operating system of Building
- Environmental impact & Influences
- The utilization of nature



Zone AA- Very Hot

Zone A- Hot

Zone B- Humid

Zone C- Very Humid

Zone D- Very Dry

Zone E- Very cold

Fig 11. Bioclimatic chart describes the adjustment of climate outside comfort zone. In A, B, C, D and E zone are outside the comfort zone. Where the climate in A, AA and B zone is hot, C is very humid, D is very dry and E is very cold. Each zone can apply different techniques to adjust for comfort. [7, 9]

Building design that respond to climate condition can be achieved by the analysis of the Bioclimatic Chart. The draw of natural factors for energy saving derives from the modification of various climate zones as in (Fig 11) to create comfort condition. The study of climates in five countries that include Australia, Japan, Singapore, United Kingdom and the United State of America is analyzed in the Bioclimatic Chart, which in Table 3 describes amount of hours in July, April and December in order to compare the differences of climates in each country. For instance, climate conditions in Australia have more hours in the comfort zone, but the climate in December is higher than the comfort zone for some period of time. Japan has climate conditions in April and December that are lower than the comfort zone. Although climate conditions are higher than comfort zone in July, Japan also has some amount of hours in the comfort zone.

In Singapore, where the temperature and humidity are higher than the comfort zone for almost the year, the main factor to design building is then focused on the prevention of heat and humidity in building.

Table 3 demonstrates temperature and humidity in each hour of July, April and December in Australia, Japan, Singapore, United Kingdom and the United State of America.

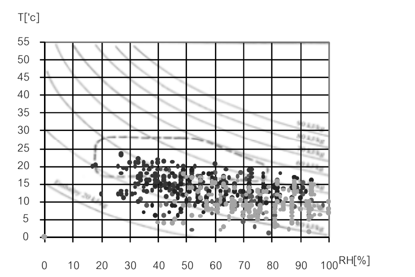
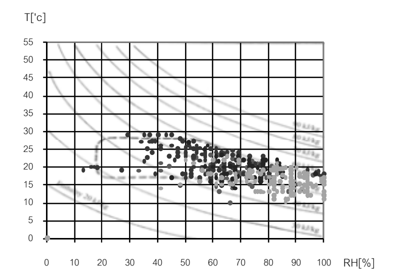
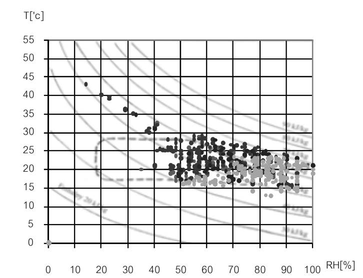
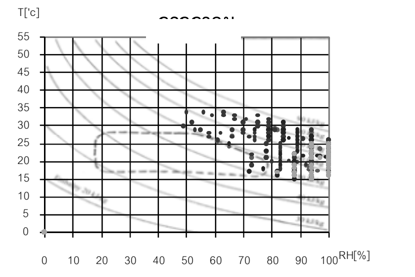
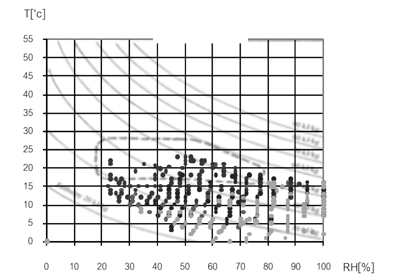
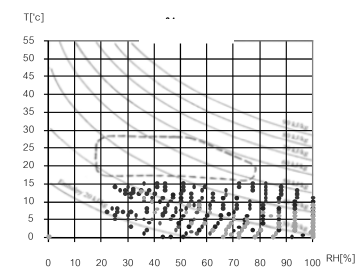
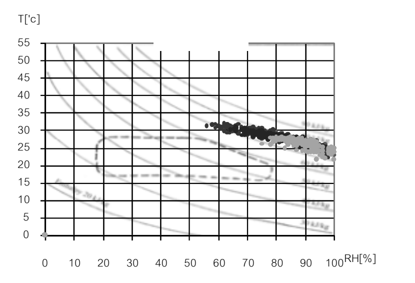
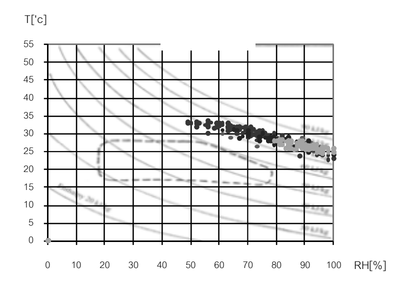
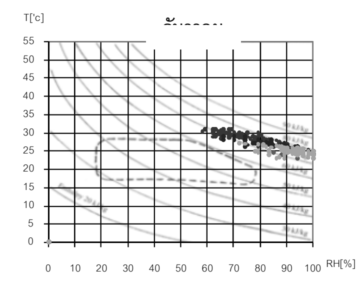
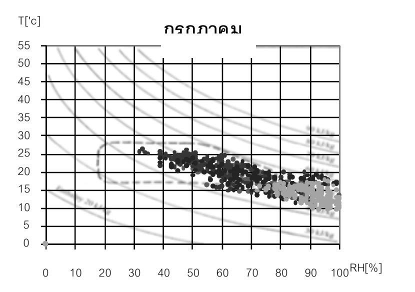
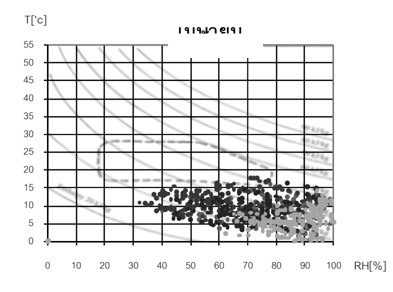
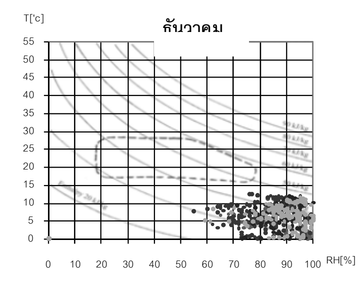
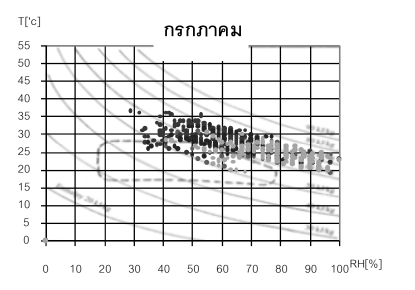
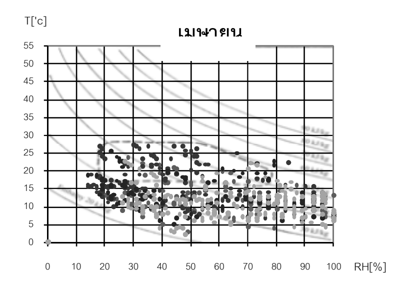
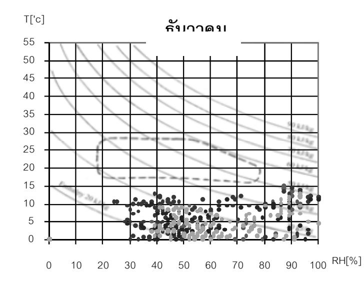
July	April	December
		
Australia		
		
Japan		
		
Singapore		
		
United Kingdom		
		
United States of America		

Table 4 demonstrates hours outside the comfort zone that can apply techniques in building design in each zone to increase comfort conditions.

Country (city)	Amount of hours per year (%)							
	comfort zone	zone A	zone AA	zone B	zone C	zone D	zone E	can't apply to comfort zone
Australia (Sydney)	15	1	0	7	5	0	37	35
Japan (Tokyo)	5	0	0	4	4	0	13	74
Singapore (Paya Lebar)	1	0	0	16	7	0	0	76
United Kingdom (London)	3	0	0	0	0	0	22	75
United States of America (New York Laguardia)	11	0	0	12	5	0	26	46

Specific characteristics of climate condition are the main criteria for the modification of comfort condition. The application of several techniques can increase hours in comfort zone. In Table 4, Australia can increase hours close to comfort zone for up to 50%, and 21% in Japan, 23% in Singapore, 22% in United Kingdom and 43% in the United States of American. This approach is successful in reducing energy consumption, which derives from the understanding of relationship between building design and climates. The way to take ultimate advantage of the climate and natural factors are the main criteria for the development of building assessment.

4.3 Material Selection as Factor for Energy Saving

Material selection for building envelope is one of the most important factors that help reducing energy consumption. Building envelope is an element next to exterior environment; therefore, heat or cool air can transfer through building envelope that causes effects to indoor environment. A large amount of energy is required to modify indoor temperature to create comfort conditions in building.

Good building envelope such as wall, roof, window or floor is important to the design regarding to climate conditions of the individual country. As a result, coefficience of transmission is essential to material selection that should respond to the climate. Material selection is considered in terms of preventing heat or cool air from exterior environment. For example, the use of glass in hot humid climate should consider about direct sunlight. When glass exposes to direct sunlight, it usually generates high surface temperature that result in the increasing of room temperature. It is recommended to choose a high insulated glass material for the hot humid climate that can cool down glass surface temperature and result in the lower mean radiant temperature for a more comfortable indoor environment

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Table 5 demonstrates quality of building envelope for the analysis in (fig. 12 and 13)

Detail	A Building Material		B Building Material	
	U Btu/(h ft^2 F)	U W/(m^2 K)	U Btu/(h ft^2 F)	U W/(m^2 K)
Roof	0.52	2.98	0.02	0.14
Wall	0.60	3.38	0.05	0.31
Glass	1.04	5.89	0.34	1.93

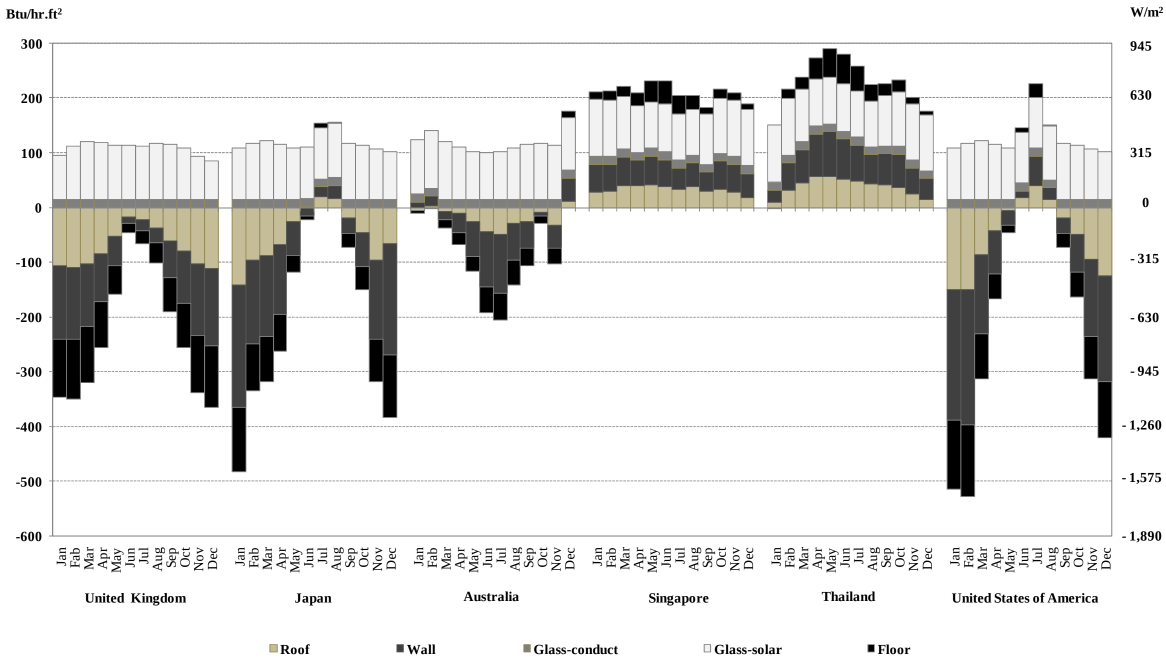

Fig 12. Demonstration of loading ratio in table 5 in A Building Material column. Material that has high coefficience of transmission and low insulation can cause higher energy consumption in indoor environment modification as a result of energy used for reducing heat or cool surface.

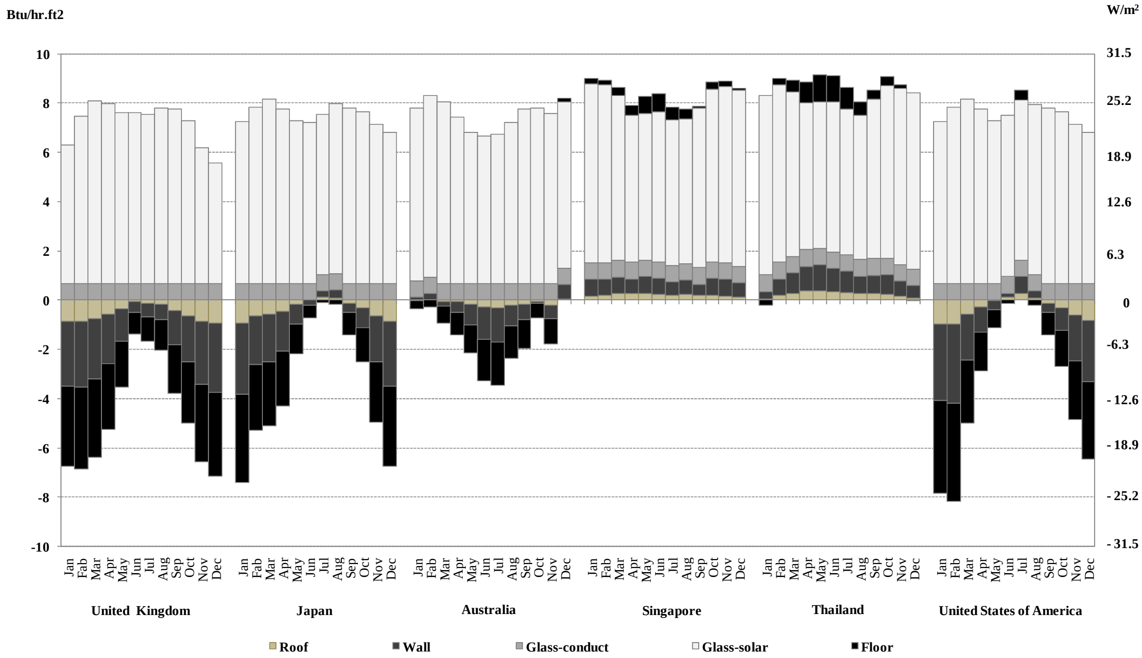

Fig 13. Demonstration of loading ratio in table 5 in B Building Material column. Material that has low coefficience of transmission and high insulation can cause lower energy consumption in indoor environment modification that is appropriate for the hot humid climate.

This paper explains the modification of environmental aspects in specific condition that is essential to the design of a weighing system for building assessment. In the design for ecology building, the important factor is to take ultimate use of natural conditions. The design that is based on climate modification can reduce 23% of energy consumption. And the design that is considered about material selection results in 25% reduction of energy consumption. The reduction of energy consumption in indoor environment accounts for the majority of total energy consumption of the building.

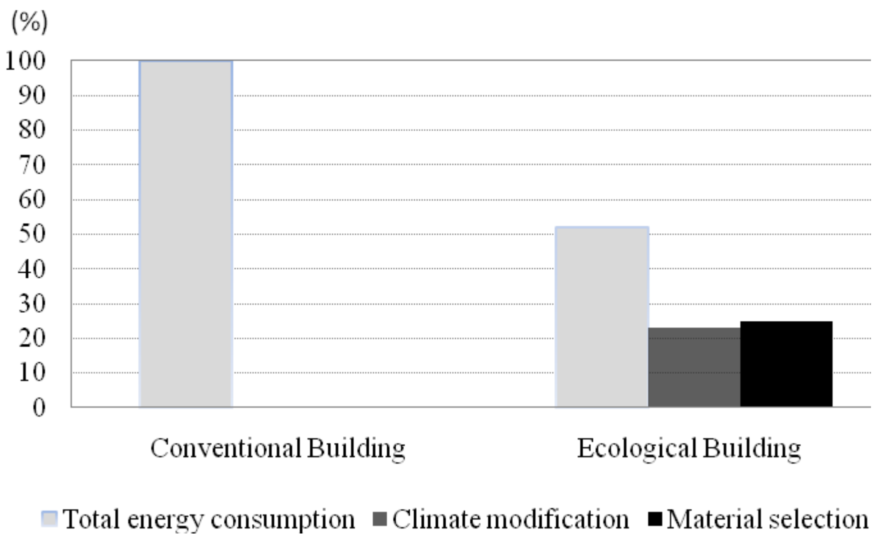

Fig 14. Demonstration of the 48% decreasing of energy consumption that derived from building design in regards to climate modification and material selection

5. Conclusion

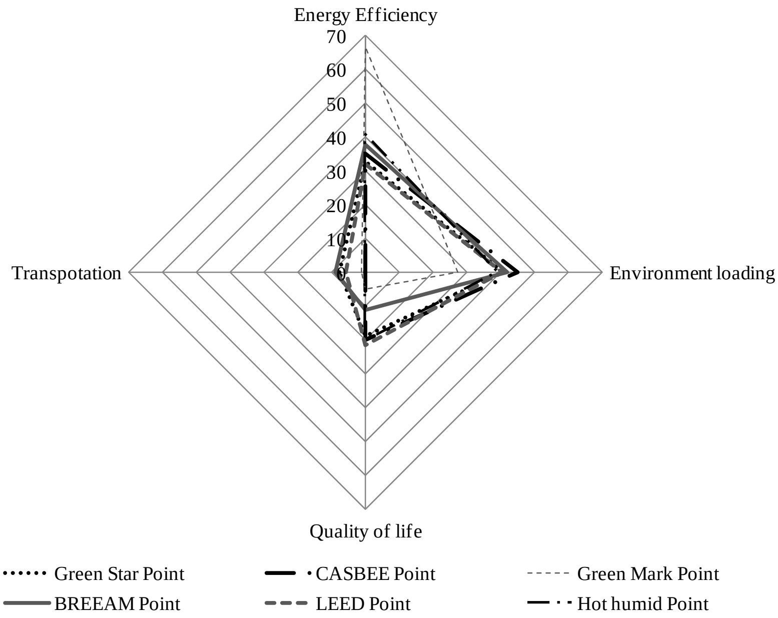

Fig 15. demonstration of the score of building assessment in each category for various assessment methods

The ecological building assessment index for hot humid region is designed for the consideration of climate, human and building factors that concern human comfort as the most important factor.

This paper studies various climate characteristics in one year that aims to find the amount of hours that reach comfort level in order to modify the environment from appropriate techniques.

The study finds that there are opportunities to create a climate close to a comfort zone that based on the characteristics of climate conditions of each country. In consideration of building aspects, insulation characteristics, coefficience of transmission play an essential role to decrease cooling load and heat transfer in building.

In order to reduce energy consumption, the design for ecological building assessment index for hot humid region has to consider the balance of energy efficiency and environmental loading, which is the point where energy and environmental impact is reduced and still achieve higher level of living quality. However, this research does not include transportation as the scope of study.

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