Evaluation of Energy and Atmosphere Section for Thailand Green Building Project Case Study

N. Patcharaprakiti and J. Saelao

Abstract—**This paper proposes a green building design and implementation of office building name Toyota Petra. The overview of building concept design in as aspects of green building are described. Thailand Green building Code under Thailand Green Building Institute composing of 7 sections are introduced. The energy and atmosphere section is evaluated in term of design, investigation, implementation and measurement. The energy and atmosphere section of green building concept consists of OTTV/RTTV, air conditioning and lighting energy consumption and energy generation from renewable. The calculation result are calculated and analyzed by using the program developed by Ministry of Energy. The result found that all of energy consumption criteria and also whole energy building consumption pass the standard criteria of building code.**

Index Terms—**Green building, building energy code, OTTV/RTTV.**

I. Introduction

Green building refers to structure and using process that is environmentally responsible and resource efficient throughout a building's life cycle from design, construction, operation, maintenance and renovation. The objective of green buildings are designed to reduce the overall impact of the built environment on human health and nature environment by efficient utilization of energy, water and material resources and to protective human occupant health, reducing waste, pollution and environment degradation. There are various kind of green building code for each country for example LEED-USA, BREEAM-UK, CASBEE-Japan, Green star-Australia, Green Mark-Singapore, HK Beam-Hong Kong.[1]. Thailand Green Building institute TGBI with cooperation between, COE, Thai Architecture Council have develop green building concept in the name of Thai's Rating of Energy and Environmental Sustainability for New construction and Major Renovation (TREES-NC). Following this concept, one of the Toyota dealer company in Thailand name "Toyota Petra" have initiated the green concept to the automobile showroom around the center part of Thailand. Among the topics of TREE-NC energy and atmosphere is the biggest part and highest mark to meet standard. In order to follow the TREE-NC in part of energy and atmosphere, there is a building energy code for energy conservation in building construction from Ministry of Energy. In this paper, the energy and atmosphere of TREE-NC as well as the building energy code for building construction are described. A case study project of Toyota Petra and building energy code simulation and the results are compared with building energy code.

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II. Thailand Green Building

The major tool for design and construction green building called TREES-NC is introduced in this section. TREES-NC is developed for both new building and renovation and it divided into two groups including 9 topics of prerequisite and 85 marks as follow in Table 1[2]. All of prerequisite item need to be passed and green building evaluation is divided into 4 level up to the mark follow as certified 30-37 points, silver 38-45 points, Gold 46-60 points and platinum 61-85 points. In this paper, energy and atmosphere topic particularly energy efficiency and renewable energy is focused. The energy building code and calculation method is also introduced. Toyota showroom building in term of energy aspect is illustrated. The energy building code program is simulated and analyzed. The building energy code of Thailand are declared by ACT Energy conservation promotion Act (B.E. 1992), Ministerial Regulation No.2 (B.E. 1995) and Ministerial Regulation (B.E. 2009) "Type/size of building and standard/method for design energy conservation building" [3]. The building code indicate that the following type of building which has area more than 2,0000 m^2 should follow this code. The Toyota Petra show room is one of building in the code by office type. The details of code are composed of building envelope, lighting, air conditioning, hot water system, whole building energy utilization and renewable energy generating system. The summarize criteria for pass this code are shown in Table II and details of calculation are described below.

TABLE I: Thai's Rating of Energy and Environmental Sustainability.

Code	Topic	Prerequisite	Mark
BM	Building Management	1	3
SL	Site and Landscape	2	16
WC	Water Conservation	-	6
EA	Energy and Atmosphere	2	20
EA P1	Quality assurance	*	
EA P2	Minimum Energy efficiency	*	
EA 1	Energy efficiency	-	16
EA 2	Renewable energy	-	2
EA 3	IPMVP	-	1
EA 4	Non hazardous Refrigerant	-	1
MR	Material and Resource	-	13
IE	Indoor Environmental quality	2	17
EP	Environmental Protection	2	5
GI	Green Innovation	-	5
		9	85

TABLE II: BUILDING ENERGY CODE CRITERIA.

Type of Building	OTTV (w/m2)	RTTV (w/m2)	Lighting efficiency (w/m2)
School/University Office building	50	15	14
Department store, Public building	40	12	18
Hotel, Hospital, Condominium	30	10	12

A. Building Envelope

Heat transfers of building envelope are composed of two major components such as Overall Thermal Transfer Value ($OTTV$) and Roof Thermal Transfer Value ($RTTV$). $OTTV$ is a control measure to cut down heat gain at building envelope and to reduce cooling load of the building. OTTV is measure of the average heat gain into a building through the building envelope and has three components follow as heat conduction through opaque wall, (Q_{wc}), heat conduction through window glass, (Q_{gc}), solar radiation through window glass, (Q_{gs}). The heat transfer through the building envelope can be expressed as [4].

$$OTTV = \frac{Q}{A} \tag{1}$$

where Q = total heat transfer through envelope (W), A = gross area of building envelope (m^2)

For an individual wall, the OTTV can also be expressed as the general form of OTTV equation for an external wall is given in equation ((1as follows:

$$OTTV_i = \frac{\varphi_{wc} + \varphi_{gc} + \varphi_{gs}}{A_i} \tag{2}$$

Q_{wc} is heat conduction through opaque wall, Q_{gc} is heat conduction through window glass, Q_{gs} is solar radiation through window glass

$$OTTV_i = \frac{\left(A_w + U_w + TD_{eq}\right) + \left(A_f + U_f + DT\right) + \left(Af + SC + SF\right)}{A_i} \tag{3}$$

where A_w , A_f wall and window area (m^2), $A_i = A_w + A_f$, U_w , U_f U-values of wall and window (W/m^2.K), TD_{eq} is Equivalent temperature difference (°C), DT Delta Temperature (°C), SC Shading coefficient of window glass, SF Solar factor (W/m^2). The parameter TD_{eq} DT , SF depend on the climate and building construction. The OTTV of the whole external wall is given by the weighted average

$$OTTV_{wall} = \frac{\sum\left(OTTV_i \times A_i\right)}{\sum A_i} \tag{4}$$

A simplified form using the Window to Wall Ratio (WWR) can be used to express the OTTV [5]:

$$OTTV_i = \left(1 - WWR\right) \times U_w \times TD_{eq} + WWR \times U_f \times DT + WWR \times SC \times SF \tag{5}$$

The $OTTV$ for roof is similar to that for walls (roof replaces walls and skylights replace window). But roof $OTTV$ is simpler since skylights are not contained in this building. To differentiate between the walls and the roofs, term Roof Thermal Transfer Value ($RTTV$ is used instead. Similarly, $RTTV$ takes into the three basic components of heat gain through the opaque roof and skylight. These are heat conduction through opaque roof, heat conduction through the skylight roof and solar radiation through skylight. The $RTTV$ can be calculated from equation [6].

$$RTTV = \left(U_i\right)\left(1 - RSR\right)\left(TD_{eq}\right) + \left(U_{rf}\right)\left(RSR\right)\left(\Delta T\right) + \left(SC\right)\left(RSR\right)\left(SF\right) \tag{6}$$

where $RTTV$ is Roof thermal transfer value (W/m^2), U_i is thermal transmittance of opaque roof W/m-°C, U_{rf} is thermal transmittance of skylight area (W/m °C), RSR คือ skylight ration of roof (skylight area/gross area of roof), TD_{eq} Equivalent temperature difference (°C), ΔT is difference between internal and external temperature, SC is Shading coefficient of skylight portion of the roof and SF is Solar correction factor for roof (W/m^2).

B. Lighting

The energy for Illumination in building exclude car parking area is concerned. The illumination energy efficiency is calculated in equation (7). Where PD is lighting power consumption per area [W/m^2], LW is summation of installed lamp power in building [W], BW is summation of installed ballast in building [W] and GR is total area in building.

$$PD = \frac{LW + BW}{GR} \tag{7}$$

C. Air Condition

Two types of air conditioners composing of package unit and window/split type unit are designed. The energy utilization and efficiency standard are calculated with two methods. The first method is calculated from ChP or in ratio of electrical energy (kW) per cooling load (ton) as shown in the equation (8). The standard of air condition should not exceed the value in Table III.

$$ChP = \frac{kW}{TON} \tag{8}$$

where TON is capability for cooling at full load which can calculate from 5.707×10^{-3}x CMM x ΔH. CMM is air volume in m^3/min (air velocity x area of air supply). ΔH is Enthalpy differentiation of air return and air supply in kJ/kg. kW is electrical power consumption of overall air condition equipments.

TABLE III: AIR-CONDITIONING EFFICIENCY STANDARD.

Type	New Building (kW/Ton)	Old Building (kW/Ton)
Package Unit	1.37	1.58
Window/Split	1.4	1.61

The second method of air condition efficiency calculation following to is calculated from energy efficiency in ratio of cooling capacity (W) per electrical shown in equation (9)

$$EnergyEfficient = \frac{Cooling\,Pacity\,of\;Air\,Condition(W)}{Rating\;of\;Electrical\;Power(W)} \quad (9)$$

Cooling capacity of air condition is Capability of air condition for sensible heat and Latent heat ventilation from air condition area in time unit (J/s) or Watts [W] and Rating of electrical power is electrical power of air compressor, fan, controller and related equipment of air conditioning system in unit Watts [W] as shown in Table IV.

TABLE IV: STANDARD ENERGY EFFICIENCY OF AIR CONDITION.

Size of air condition [W]	Energy efficiency [W/W]
> 8000	3.22-4.10
8000 – 12000	3.22-4.10

D. Renewable Energy

A 3.6 kW rooftop photovoltaic system is designed and installed in this building. The system is composed of 18 modules of 200 W solar array monocrystalline 3.6 kW of grid Tie inverter. The solar energy is calculated based on Thailand solar radiation 18-19 MJ/year and 4 hours of peak sun.

E. The Whole Energy and Renewable Energy

Whole energy of is the most important of energy criteria items. If whole building energy consumption pass the criteria then it will pass both of law of energy conservation as well as green building evaluation even though OTTV/RTTV, lighting building or energy efficiency of air condition will pass the criteria or not. The criteria of whole energy consumption are determined by reference building from the code.

III. PROGRAM SIMULATION

The Toyota Petra automobile showroom has 2 floors including office and garage zones follow as pre delivery, sale office, safe manager, pantry, service body paint, control room, Electrical room, tool part, store part, O/H, Claim, Oil and Comp and etc. The perspective of building is shown in Fig. 1. There are five zones containing air conditioning and also receive external solar radiation which use to calculate OTTV such as showroom, store and obeya, MD, Customer room as shown in Fig.2. In order to calculate the building energy code criteria, the Building Energy Code (BEC) program has been developed by Department of Alternative Energy Development and Efficiency, Ministry of Energy, Thailand [7]. The program includes of three parts follow as input part, building model and calculation part and report part. The input database part is composed of include Envelope (material, component of section, section of wall, and wall), lighting, air condition, hot water system and photovoltaic system. The materials are constructed to component of section, section of wall and wall respectively. The building model is composed of area zone, wall and section of wall in each direction or each zone including number of lighting fixtures and air conditions. The input databases of five zones for OTTV calculation are shown in Table V. Then building energy calculation is analyzed. Then, the calculation method which describe in previous section is analyzed the database in building model.

Fig. 1. Perspective view of building.

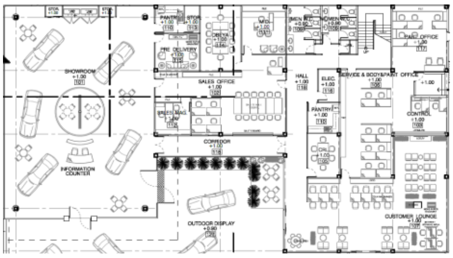

Fig. 2. Floor plan of the building zone area.

TABLE V: INPUT DATABASES OF FIVE ZONES FOR BEC PROGRAM CALCULATION.

Room & Direction	Air condition system	Material	Type of	Surface m2	Opaque Properties: Thermal Coductivity (W/mK)	Opaque Properties: Density (kg/m3)	Opaque Properties: Specific Heat (kJ/kg K)	Transparent Properties: Visible Ray Transmittance	Visible Ray Reflectance	Solar Energy Transmittance	Solar Energy Reflectance	Solar Energy Absorb	U-value (W/m2 K)	Shading Coefficient	SHGC
Showroom	Package 4 Ton														
South		Clear Float Glass 12 mm.	Trans.	117.49	-	-	-	0.65	8.7	45.3	7.6	47.1	3.97	1	0.54
		Aluminium Composite	Opaque	20	211	2672	0.89	-	-	-	-	-	-	-	-
West		Concrete	Opaque	46	0.47	1280	0.84	-	-	-	-	-	-	-	-
		Glass block	Opaque	81	-	-	-	-	-	-	-	-	-	-	-
Pantry	Split type 1 Ton														
West		Clear Float Glass 6 mm.	Trans.	18	-	-	-	0.88	8	80	7	13	5.74	1	0.82
		Concrete	Opaque	14	0.47	1280	0.84	-	-	-	-	-	-	-	-
Store	Split type 1 Ton														
West		Clear Float Glass 6 mm.	Trans.	17	-	-	-	0.88	8	80	7	13	5.74	1	0.82
		Concrete	Opaque	20	0.47	1280	0.84	-	-	-	-	-	-	-	-
Obeya	Split type 1 Ton														
West		Clear Float Glass 6 mm.	Trans.	10	-	-	-	0.88	8	80	7	13	5.74	1	0.82
		Concrete	Opaque	23	0.47	1280	0.84	-	-	-	-	-	-	-	-
MD Room	Split type 1 Ton														
West		Clear Float Glass 6 mm.	Trans.	9	-	-	-	0.88	8	80	7	13	5.74	1	0.82
		Concrete	Opaque	10	0.47	1280	0.84	-	-	-	-	-	-	-	-
Customer Lounge	Package 4 Ton														
East		Clear Float Glass 6 mm.	Trans.	42	-	-	-	0.88	8	80	7	13	5.74	1	0.82
		Concrete	Opaque	63	0.47	1280	0.84	-	-	-	-	-	-	-	-
		Aluminium Composite	Opaque	14	211	2672	0.89	-	-	-	-	-	-	-	-
Roof	-	Metal Sheath	Opaque	284	0.9	2000	1	-	-	-	-	-	-	-	-

IV. Result and Discussion

The reports of program are displayed in each zone and overall of OTTV/RTTV, lighting efficiency, air condition energy efficiency, photovoltaic electricity generation and whole energy consumption. All results of simulation are passing the code requirements as shown in Table VI.

TABLE VI: Report from BEC program.

Value	BEC code	Simulation	Unit
OTTV	50	48.12	W/m^2
RTTV	15	11.33	W/m^2
Lighting	14	8.49	W/m^2
Air condition	3.22-4.10	3.52	COP
PV system	-	4,283	kWh/yr
Whole energy consumption	42,728.85	28,885.11	kWh/yr

V. Conclusion

This paper proposes a green building design and implementation of office type building named Toyota Petra showroom which located in central area of Thailand. The overview of building concept design in as aspects of green building are described. Thailand green building code under Thailand Green Building Institute is introduced. The energy and atmospheric section is evaluated in term of design, investigation, implementation and measurement. The energy and atmospheric of green building concept consists of OTTV and RTTV, air conditioning energy consumption, lighting energy consumption and energy generation from PV system. The calculation result of energy utilization and consumptions are calculated by using the program developed by ministry of energy. The result found that all of energy consumption criteria and also whole energy building consumption pass the standard building code criteria.

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