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Carbon (CO_2) Footprint Reduction Analysis for Buildings through Green Rating Tools in Malaysia

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Abstract

This study aims to identify and discuss the Green House Gas (GHG) emission reduction through Green Rating Tools in Malaysia in recognition of the environmental and economic threats posed by climate change. One sector receiving particular attention worldwide is the building industry that has grown significantly and responsible for more than 40 percent of global energy use. As much as one third of global GHG emissions, both in developed and developing countries are from building energy use. In view of this, the global community has taken various measures to mitigate the impact which includes the call for reduction of fossil fuel through energy efficiency and substitution of renewable energy, encouraging the building industry to adopt construction of sustainable buildings known as green buildings (GB).Green building focuses on increasing the efficiency of resource use – energy, water, and materials – while reducing building impact on human health and the environment during the building's lifecycle, through better siting, design, construction, operation, maintenance, and removal. GB is certified through Green Rating Tools (GRT) to establish energy savings and GHG emission reductions.

*Keywords:*Green Rating Tools; Energy Modelling; Overall Thermal Transfer Value (OTTV)

1. Introduction

Greenhouse gas emission from fossil fuel use has been increasing at an alarming and it is causing the global warming. Global average temperature has risen by 1.4°F over the past century, and over the next hundred years, it is expected to rise by 2°F to 11.5°F. This translates to large and potentially dangerous shifts in climate and weather patterns leading to extreme conditions. [2] What worries particularly is the rate of growth of emissions: between 1971 and 2004, carbon dioxide (CO_2) emissions, including through

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the use of electricity in buildings, is estimated to have grown at a rate of 2.5% per year for commercial buildings and at 1.7% per year for residential buildings. [1]

Malaysia has committed to reduce its greenhouse gas (GHG) emissions by up to 40% per capita by year 2020 as compared to year 2005. Data extract from Malaysia's statistic shows that, the CO_2 emission has increased roughly by 40-fold, while the population increase just by about 3 fold increases [3].

2. Methodology

Reviewing GRTs to identify its requirement or compliance in reducing of CO_2 emission. Each GRT has its own sets of prerequisites and credits with varying score weightages. Each of these categories carries certain weightages or credit points that will be added up to a final total score, where higher the score the higher the awarded rating. The rating starts from Certified as lowest level, intermediate level as Silver and Gold and the highest level as Platinum. In our case study, we will analysis the energy efficiency requirements of GRTs. From our review, we have identified that the GRT require buildings seeking green certification are subjected to show a reduction in energy performance through a process known as energy modelling and Overall Thermal Transfer Value (OTTV) conformance. Both these requirement requires a building known as design case building to be measured or compared against a baseline building. The baseline building refers to the same building but design parameters are referenced to baseline values stipulated in reference standards such as Malaysian Standard (MS)1525 and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1.2010. Building seeking LEED certification is required to be in compliance with ASHRAE 90.1.2010 while buildings seeking GBI certification is required to comply to MS1525 baseline parameters. Both these standards provide reference for energy efficiency requirements. Energy modelling would be carried out by using approved software that conforms to (ASHRAE) 90.1-2010 and or Malaysian Standard (MS) 1525 depending on the GRTs [8] [9]. GBI requires additional verification through the establishment of Overall Thermal Transfer Value (OTTV) calculations to determine building's passive design performance. Lower than $50W/m^2$ of OTTV is required by GBI to show that the building is energy efficient building. First approach will be to establish the conformance to OTTV requirement through passive design improvement. Once this is achieved meaning an OTTV value of lower than $50W/m^2$ is sought. Then the energy modelling will be carried to establish the required savings. Again the proposed improvement is implemented or suggested based on cost and ease of implementation. Since energy modelling involves both passive and active energy performance design, hence improvements can be in the form of active and passive features. Each proposed feature is based on lower implementation cost and it overall energy reduction impact. This process is repeat until the desired energy efficiency is achieved. The WWR for energy modelling is only considered for air conditioned space only as required by the software.

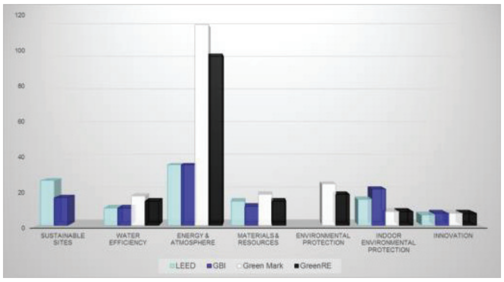

Figure 1: GRT sub category weightage[4, 5, 6, 7].

2.1 Energy Modelling

The energy modelling software used in this case study is Carrier Hourly Analysis Program (HAP) Version 4.50. It consists two segments, one to calculate the heat load of a building and the other the energy efficiency of a building. We would only be reviewing the energy efficiency aspect of the software which is relevant to our case study. Information about the building's Heating Ventilation and Air conditioning (HVAC) design parameters, equipment selection, equipment efficiency, heat load from occupant and equipment, fresh air, infiltration, proposed indoor temperature, airflow, lighting levels, space utilization, building construction material parameters occupancy profile, weather data and other key information are provide as input to the energy modelling software simulation. Apart from this energy modelling requires other inputs such as operating hours, internal partition material type, lighting controls, daylighting, ventilation needs, building orientation and external shading factors. Refer to table 2 for the details of input parameters. The baseline data is available or stated in the standards such as MS1525 and ASHRAE 90.1.2010. While the design case building systems are recognized and accepted as being energy efficient and listed in MS1525 as recommendation for energy efficiency application. Energy modelling is able to evaluate passive and active energy efficient features. Architectural design that provides shading, reducing heat gain through building envelop such walls and windows is defined as passive energy efficient features. Baseline values for building envelop is only available for building walls and windows, where the u-value is specified. Any improvement beyond this is considered to be an effort towards energy efficiency. Unlike mechanical and electrical system, where baseline values are values provided for whole range of systems as shown in table 3, applicable to our case study building. Data shown as design case in table 2 are parameters that were introduced to improve the energy efficiency of the design case building. All this information is provided as input to the modelling software. The result of energy modelling is shown in table 3. Energy modelling is able to produce hourly energy performance of a building and it can be programmed on to provide energy consumption on daily, weekly, monthly and yearly energy use. [8] [9]

2.2 Overall Thermal Transfer Value (OTTV)

Studies shows that heat flows in or out of a building throughout a day depending on the temperature difference or gradient between its internal and external wall surfaces. Especially so when a building is air conditioned, where external heat can come in or out of building through its walls and it can happen throughout the day. Therefore, to evaluate building envelop design, a criteria called overall thermal transfer value (OTTV) has been adopted. OTTV is an index for comparing the thermal performance of buildings, it is a measures of the average heat gain into a building through building envelop consisting of three major components (i) conduction through opaque walls, (ii) conduction through window glass and (iii) and solar radiation through window glass and the unit of measure is W/m^2. The OTTV aims at achieving the design of building envelope to cut down external heat gain and hence reduce the cooling load of the air-conditioning system. The OTTV calculation general is shown in equation (2), consisting of 3 distinctive section, $15\alpha\,(1-WWR)U_w + 6\,(WWR)\,U_f + (194 \times OF \times WWR \times SC)$, each of this represents different aspect of heat gain of a building, refer figure 2 below. Each of this will be calculated and the overall OTTV will be established. The building orientation contributes significantly to the overall performance of the building envelope.

To design the building envelope, a design criterion known as the overall thermal transfer value (OTTV) has been adopted. The OTTV aims at achieving the design of building envelope to cut down external heat gain and hence reduce the cooling load of the air-conditioning system.

The OTTV of building envelope is given by the formula below as equation (1).

$OTTV = \{(A_{01}\ OTTV_{01}) + (A_{02} x\ OTTV_{02}) + \ldots.. + (A_{0n} x\ OTTV_{0i_n})\}/(A_{01}+A_{02}+..+A_{oi})$ **(1)**

Where,

A_{0i} is the gross exterior wall area for orientation i; and

$OTTV_{0i}$ is the OTTV value for orientation "i" from equation **(1)**

For a fenestration (openings in a building such as windows, doors, louvres and vents) at a given orientation, the formula is given as below [8]:

$OTTV_i = 15\alpha\ (1-WWR)\ U_w + 6\ (WWR)\ U_f + (194\ xOF\ xWWR\ x\ SC)$ **(2)**

Where,

WWR is the window-to-gross exterior wall area ratio for the orientation under consideration;

The shading coefficient of a shading system is the product of the shading coefficients of its sub-systems, for example $SC = SC_1 \times SC_2$

where,

SC is the effective shading coefficient of the fenestration system;

- SC_1 is the shading coefficient of sub-system 1 (e.g. glass); and
- SC_2 is the shading coefficient of sub-system 2 (e.g. external shading devices)

The shading coefficient for glass is the value assessed at an incident angle of 45 ° to the normal [8].

Table 1: OTTV Components of Equation 2

Description	Expression
Heat conduction through walls	$15\alpha\ (1-WWR)\ U_w$
Heat conduction through windows	$6\ (WWR)\ U_f$
Solar heat gain through windows	(194 xOF xWWR x SC)

Table 2: Base and Design Building Parameters for Energy Modelling Input [9]

Description	Baseline	Proposed
Simulation Weather (selected from software)	Kuala Lumpur, Malaysia	Kuala Lumpur, Malaysia
Location GPS Coordinates	3° 10' 44.742" N 101° 46' 24.823" E	3° 10' 44.742" N 101° 46' 24.823" E
Number of Floors	29	29
Office Floors	Grd, Floor 1 & 8 to 28	Grd, Floor 1 & 8 to 28
Parking Floors	Floor 2 to 7	Floor 2 to 7
Gross Floor Area (m^2)	14,169.0	14,169.0
Net Floor Area (m^2)	10,570.0	10,570.0
Conditioned Space (m^2)	13,073.5	13,073.5
Window to Wall Ratio	48%	48%
Gross Wall Area (m^2)	4,413.0	4,413.0
Gross Vertical Window Area(m^2)	2,239.0	2,239.0
Wall Type (u-value)	2.80	2.56Wm^{2}K
Window Type (u-value)	5.70	5.70Wm^{2}K
Energy Type	Electricity	Electricity
Non-Conditioned Area (m^2)	1,095.5	1,095.5
Total Refrigerant Tonnage(RT)	1450	900
AC Equipment Type	Chilled Water Air Handling Unit	Chilled Water Air Handling Unit
Chilled Water Supply/Return Temperature (Delta –T)	44.0/54.0 (14F)	44.6/53.6 (14F)
Condenser Water Supply/Return Temperature (Delta –T)	87.0/97.0 (10F)	87.0/96.4 (10F)
Chiller Type	Water Cooled Centrifugal	Vertical Screw
Chiller Input Power	0.650kW/RT	0.592kW/RT
Primary Chilled Water Flow Rate	2040.0	1191.6 US Gallon/minute
Condenser Water Flow Rate	2600.0	1350.0 US Gallon/minute
Lighting	Fluorescent 2x36W (T8)	Fluorescent 2x28W (T5)
Ballast Type	Magnetic	High Frequency Electronic
Office Area Lighting Density (w/m^2)	14.86	6.7
Office Area Lighting Level (Lux)	414	304

The calculated OTTV for design case building is 44.0 W/m^2

Similarly, the Roof Thermal Transfer Value (RTTV) is required if the roof area of the building is very significant and in the case of an air-conditioned building, the concept of Roof Thermal Transfer Value (RTTV) is applied if the roof is provided with skylight and the entire enclosure below is fully air-conditioned. GBI recommends that OTTV=< 50 and RTTV=<25 as part of its requirement for a building being considered energy efficient in addition to energy modelling. [7]

Table 3: Extract for Energy Modelling Results

Load Description	Baseline Building Energy (kWh)	Design Building Energy (kWh)	Savings (%)
Interior Light	373760.0	253347.0	32.0
Space Heating	0.0	0.0	0.0
Space Cooling	392062.0	319035.0	20.0
Pumps	147493.0	117580.0	-11.0
Heat Rejection	523685.0	228952.0	56.0
Fans Interior	290070.0	0.0	100.0
Receptacle Equipment	373740.0	250036.0	33.0
Elevator	190494.0	190884.0	0.0
Mechanical Ventilation	292240.0	365300.0	-25.0
Interior Light (Non AC)	29224.0	73060.0	-150.0
Total	2612768.0	1798194.0	31.0
CO_2 Equivalent (kg)	1230618.2	846945.0	31.0

The negative values show that those systems are less efficient than the baseline because the project team opted for less efficient system in favor of lower implementation cost. The interior fans are able to achieve 100% efficiency because the baseline recommendation is mechanical ventilation but the design building uses natural ventilation. Fair amount of work has been put in to review the energy modelling and OTTV calculation to determine the energy efficiency level until the desired results is achieved. Implementing GRT requires additional cost over baseline building, hence the initiative to lower the CO_2 footprint of the design case building involves reviewing all the available credits prior to attempting energy credits. Credits are selected based on its impact on overall construction cost, generally as reported based on research done by Enermodel Engineering Denver USA, a GB seeking LEED certification may have an incremental cost of 1% to 13% over total construction cost depending on the size of the building and the certification level sought [10]. Attempts are made to establish energy credits starting from passive building design to active energy systems such as air conditioning and mechanical ventilation system. Apart from design perspective, we are also challenged by certain requirement imposed by the building owner, particularly in this case a less efficient facet glass and having full glass building prevented us from having external shading devices. Hence in order to achieve targeted efficiency, we have introduced higher efficient air conditioning chillers with constant volume air distribution system, daylighting control, natural ventilation for staircases and plantrooms. Additional floor insulation for top floor roof and for 3 levels of outdoor platforms. Window to wall ratio was reduced from 54% to 48% from the original design. Overall the building design is 31.0% more efficient that a baseline building, and higher than the 30% efficiency required by GRT compliance seeking Gold certification and an OTTV of less than 50.0W/m^2.

3. Conclusion

This paper has summarized the process of achieving GHG reduction through the implementation of GRT for buildings. Both our analysis shows a significant impact on reduction in CO_2 emission through energy modelling and OTTV analysis. There is various approved energy modelling software that are able to provide energy performance analysis for both passive and active building designs. OTTV analysis is limited to passive building design assessment focusing on the building envelope typically carried out to ascertain energy performance for smaller residential buildings. It is also effective on high rise residential buildings where active analysis is restricted by individual tenant/owner preferences towards internal fitting out of systems like lighting, cooking method either gas or electricity based appliances, air conditioning system and other comforts. As such energy modelling approach will be a worthwhile option to consider for single tenanted or rentable commercial buildings to establish energy efficiency. Apart from this, when a building seeks higher level of GB certification such as Silver, Gold and Platinum, it becomes mandatory to carry out full energy modelling to ascertain and verify its energy performance. Both energy modelling and OTTV are compulsory compliances as required by GRT through compliances to international standards such as ASHRAE as recognized by Clean Development Mechanism (CDM) defined in Article 12 of Kyoto Protocol for emission reductions. It can be proven that CO_2 emission reduction is achievable through the implementation of Green Building Certification Tools.

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Nomenclature

OTTV	Overall thermal transfer value (W/m^2)
RTTV	Roof thermal transfer value (W/m^2)
kWh	kilowatt hour
WWR	Window to Wall Ratio
α	Solar absorptivity of opaque wall
U_w	Thermal transmittance of opaque (non transparent surface) system (W/m^2)
U_f	Thermal transmittance of fenestration (such as windows, doors, louvres, opening) (W/m^2)
SC	Shading coefficient
OF	Solar Orientation factor
RT	Refrigerant Ton (cooling load/capacity)
u-value	Heat transfer coefficient
Delta T	Temperature difference between to points
F	Fahrenheit
Lux	Lighting level Lumen/m^2
SC_1	Shading coefficient of sub-system 1 (e.g. glass); and
SC_2	Shading coefficient of sub-system 2 (e.g. external shading devices)

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Biography

Surenthira Stephen Ramachanderan was born in Ipoh, Perak, Malaysia on 19th April 1966. He obtained his Bachelor's degree in Electrical Engineering from University of Malaya. He is a Professional Engineer registered with Board of Engineers Malaysia, Member of Institute of Engineers Malaysia, registered Electrical Energy Manager with Energy Commission of Malaysia and LEED AP registered with United States Green Building Council and a trainer/facilitator with Institute Engineers Malaysia. Currently the Principal at Pinacle Quest Consulting Engineers S/B, a company focusing on Mechanical, Electrical, Green, Energy Efficiency, Renewable Energy and Power Quality with over 25 years of extensive hands-on and design experiences in facilities operation, maintenance, electrical, sustainability consulting and energy management services. Presently pursuing his Masters in Heriot Watt University Malaysia Campus.

Vinod Kumar Venkiteswaran was born in Kochi, India on 1st November 1979 .He obtained his Bachelor's degree in Mechanical Engineering from Calicut University in 20011, Master's Degree in Energy systems engineering from Visvesvaraya Technological University in 2007 and PhD from Universiti Teknologi PETRONAS in 2104 .

He has done research works in the area of Alternative energy especially in Biodiesel and solar energy. He has publications in journals such as IJSE(2009) JAS (2012), IJENS (2013) etc. and has presented more than 20 papers in various international conferences.

Presently working as Assistant Professor in Heriot Watt University Malaysia Campus, he is a Certified Energy Manager and has research interests in Alternate fuels in IC engines, Biofuels, Renewable & Alternative energy, Energy management & Conservation, Green Buildings and Swirling Fluidized Bed.