OVERALL TRANSFER THERMAL VALUE (OTTV) INDEX ASSESSMENT ON 4G11 TOWER, MINISTRY OF WOMEN FAMILY AND COMMUNITY DEVELOPMENT, PUTRAJAYA, MALAYSIA

Amirul Amin Ismail[1] & Azman Zainonabidin[2]
Department of Architecture, Faculty of Architecture Planning and Surveying, Universiti Teknologi MARA (Perak), Malaysia

[1]amiru683@perak.uitm.edu.my
[2]azman906@perak.uitm.edu.my

ABSTRACT

In the Eleventh Malaysia Plan, Malaysia will be pioneering a sustainable city development by retrofitting all Government buildings to be energy efficient. Overall Thermal Transfer Value (OTTV) is a measuring tool of thermal efficiency for building envelope. A case study on iconic 4G11 Tower is carried out to determine the possibility of improving OTTV assessment for existing high-rise office building thus enhance the building's overall efficiency. Through this exercise, several variables influence the OTTV score such as U-Value, Shading Coefficient (SC) and Window-to-Wall Ratio (WWR). Characterised by Baseline Design, MS1525 Design and Platinum Design, this will be a precedent of OTTV assessment for high-rise office building typology.

Keywords: Sustainability, Energy Efficiency, Overall Transfer Thermal Value

1.0 INTRODUCTION

Sustainability development is one of the most debated topics in Built Environment Industry. It is because the industry is responsible for 30% of global greenhouse gas emission (GHG). The aftermath of rapid globalization has taken its toll as the natural resources are severely depleted thus contributing to multiple environmental issues such as climate change and global warming. Therefore, green building initiatives such as Building Research Establishment Environmental Assessment Method (BREEAM) in United Kingdom and Leadership in Energy and Environmental Design (LEED) in United States are founded to address the importance of sustainability in built environment. Energy efficiency in the building is becoming an essential factor towards holistic sustainable development. Malaysia, for instance, has Green Building Index (GBI) to spearhead our nation's green building initiatives by developing building energy efficiency or building energy performance standards for existing and new buildings.

Overall Transfer Thermal Value (OTTV) method was first introduced by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). It is a tool for measuring thermal efficiency in building envelope of the air-conditioned building. Then this developed into other countries such as Hong Kong, Singapore, Thailand, and including Malaysia. In Malaysia, air-conditioning contributes a substantial 60% of energy consumption in office buildings. While in Hong Kong, a staggering 90% of energy consumption is attributed from buildings. Therefore, the OTTV submission is mandatory in Hong Kong, in accordance with energy efficiency regulation for new commercial and hotel buildings. This is to ensure their building is energy efficient and in compliance with building efficiency goals. A similar situation applies in Malaysia as Non-residential buildings, with above 4000 m^2 of the air-conditioned area need to submit the OTTV calculation. This initiative can be an encouraging start to raise awareness and promote sustainable development. The OTTV index assessment is utilized to control energy use in building envelope. The goal is to minimize the energy consumption of air-conditioning by reducing the heat through the building envelope, thus improving the energy efficiency of the building.

Economic Planning Unit (2015) stated in the Eleventh Malaysia Plan that the Malaysian Government will be the front-runner in sustainability development by retrofitting all existing Government buildings to be energy efficient. Further action has been made by appointing groups of experts in green building to carry out an assessment of existing building envelope which will influence Overall Transfer Thermal Value (OTTV) index. Perdana Putra, the 5-storey Prime Minister Department Complex is the first successful project. This paper will conduct an assessment on 4G11 Tower's building envelope without changing the physical appearance or façade of the building. This 38-storey tower office is one of the nation's pride and iconic high rise building in Putrajaya, Malaysia. It houses the Ministry of Women Family and Community Development. 4G11 Tower currently has OTTV value or Baseline Design score of 77.43 Wm^2. The outcome of this assessment will determine the possibilities of retrofitting existing buildings particularly for high-rise office towers to be energy efficient, and in unison with the Government's aspiration of making Putrajaya as

Sustainable Development Administrative Centre and Putrajaya Green City 2025 into a reality.

2.0 LITERATURE REVIEW

2.1 Building Envelope and Building Energy Index (BEI)

Energyland (2015) emphasized that building envelope is the separator between internal and external space thus acting as a thermal barrier. It is essential that the building envelope is able to regulate the interior temperatures and consume the minimum energy possible to maintain thermal comfort. Malaysia is hot and humid climate and generally receives 12-hours of sunlight per day. This is where the importance of regulating building envelope as it can reduce the energy capacity for cooling while in contrast for temperate climate region, it will reduce the amount of energy required for heating.

In Malaysia, a stunning 60% of energy consumption in typical office building contributed from air conditioning. Therefore, by proper regulation of building envelope such as OTTV assessment, this will help to ease off the cooling load generated by air conditioning unit and reduce the Building Energy Index (BEI). BEI is the medium to determine the energy consumption in the building. The OTTV is an essential factor as they can be a huge influence that reflects the energy consumption of the buildings. The Ministry of Energy, Telecommunications, and Posts (1989) pioneered one of the earliest building criteria with four types of energy consumption in Malaysia. They are:

i) BEI is equivalent to 240 kWh/m^2/year. This is among energy-intensive buildings in Malaysia.

ii) BEI is equivalent to 166 kWh/m²/year. This reflects an average range of construction and energy use features in Malaysia.

iii) BEI is equivalent to 136 kWh/m²/year. This reflects the level of energy efficiency expected to be achieved by the Guidelines.

iv) BEI is equivalent to 98 kWh/m²/year. This reflects the level of energy efficiency in building.

On November 9, 2014, the Prime Minister Department Complex, known as Perdana Putra has received the highest certification for green building in Malaysia which is the Green Building Index (GBI) Platinum Certification. Perdana Putra also categorized as high-performance Green Building by GBI. Perdana Putra's energy intensity has dropped significantly from score of 135 kWh/m²/year to 85 kWh/m²/year. This 5-storey building is now approximately 38% more efficient than before and considered to be a huge success for the first retrofitting project. This pilot project is proven to be a catalyst in green building development as Putrajaya will continue to advance into a green smart and a model township for Sustainability and Green Technology in 2025.

2.2 Fundamental and formulation of Overall Thermal Transfer Value (OTTV)

The fundamentals of Overall Thermal Transfer Value (OTTV) are the building envelope must be totally enclosed and in air-conditioned space. The solar heat gain through the building envelope constitutes a considerable share of the cooling load, therefore by utilizing OTTV assessment will reduce external heat gain and ultimately lessen the cooling load of the air conditioning system. Saidur, Hasanuzzaman, Hasan and Masjuki (2009) considered OTTV is better thermal performance index tools compared to thermal transmittance (U-value) because the impact of direct solar energy on building envelope of air-conditioned buildings has taken into account. The OTTV comprises of three major components as affirmed by Lam (2000). They are;

i) Heat conduction through opaque walls.
ii) Heat conduction through window glass.
iii) Solar radiation through window glass.

(i) (ii) (iii)

$$[15\ \alpha\ (1\text{-}WWR)Uw] + [6(WWR)Uf] + [194 \times CF \times WWR \times SC]$$

α	= Solar absorption (color of the wall)
WWR	= Window to Wall Ratio
Uw	= U-value of the wall
Uf	= U-value of the window (Refer to glass specification)
CF	= Correction Factor (Table 4 MS1525)
SC	= Shading Coefficient (Table 5, 6 & 7)

According to Department of Standards Malaysia (2007) clause 9 of MS 1525, it is stated in Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings that any non-residential air-conditioned buildings exceeding 4000m² and above need to submit OTTV calculation for energy environment control initiative. Moreover, for building compliance the OTTV calculation should not be exceeding 50 W/m², and the visible transmittance of the daylight fenestration system should not be less than 50%.

2.3 Methods of improving Overall Thermal Transfer Value (OTTV)

Arguably the OTTV method does not consider internal shading devices such as blinds and curtains. It also does not consider the application of green walls on the building and solar reflection or shading from adjacent buildings. It is because blinds and curtains are considered as interior accessories while predetermining solar reflection or shading from the adjacent building is proven to be quite a complicated task because too many variables must be considered. However, Green Building Index (2011), has several suggestions to improve OTTV such as:

i) Identify which component contributes the most OTTV such as glazing.
ii) Review Solar Correction Factors (CF) in Table 4 of MS1525. Table 4 specifies CF for the various fenestration orientation. A fenestration system may consist of shading device, glazing material, or a combination of both;
iii) Review glass selection & its Shading Coefficient (SC). To choose glass with lower U-value, but shall not reduce the Visible Light Transmittance (VLT);
iv) Review sunshades & it Shading Coefficient (SC) factor in Table 5, 6 and 7 of MS1525. Table 5, 6 and 7 specifies SC of external shading devices. External shading devices can be proposed or improved especially to the façade which contribute most OTTV;
v) Review Window-to-Wall Ratio (WWR). The WWR can be improved by reducing window area, especially to the west façade. Spandrel glass also can be introduced.

Hui (1997) also asserted in his findings that the heavyweight construction gives better thermal performance compared to lightweight construction because of heat passage resistance factor. Thicker wall tends to be more heat resistant compared to the thin wall. However, for high-rise office such as 4G11 Tower, this theory is not practical for high-rise building as the additional dead weight will affect the structural integrity. Moreover, this will affect the architectural expression of the tower. The probable solution is by using high performance glazing such as Low-emissivity (Low-E) glass. It is lightweight and has high strength of thermal insulation. This glass also able to minimize overheating in a hot climate, therefore reducing CO^2 emissions associated with air conditioning to the atmosphere. Solar heat gain through windows contribute more than 70% thermal transfer into the building. Therefore, improving OTTV of the building is essential because it does not only provide thermal comfort for the end user but also a huge contributing factor of energy efficiency for the building

3.0 METHODOLOGY

Primary data collection was made via a case study of 4G11 Tower while the secondary data collection is obtained through various reading materials. Information retrieved from the secondary data such as building envelope, current statistics, and concept and formulation of OTTV are in the literature review. The 4G11 Tower is a high-rise office building of Ministry of Women Family and Community Development, Lot 4G11, Putrajaya, Malaysia. Building information such as façade area and window area of all four elevations of 4G11 Tower are collected as the constant of OTTV calculations. Existing building specifications i.e.

building envelope such as glass type, thickness and properties will be the basis of Baseline Design.

Data collected will be put into 3 different classifications, Baseline Design, MS1525 Design, and Platinum Design. Baseline Design is the building's existing OTTV index, while MS1525 Design in compliance with GBI Malaysia certification and Platinum Design is the maximum efficiency that can be achieved through this exercise. The data simulation is based on three criteria of OTTV formula. They are heat conduction through walls, heat conduction through window glass, and solar radiation through window glass. These three criteria will be calculated with variables of U-Value, Shading Coefficient (SC), and Window-to-Wall Ratio (WWR). The objective is to achieve better design efficiency without compromising the existing façade appearance and all the architectural features of the building. Figures from data are calculated and analysed into the overall OTTV equation.

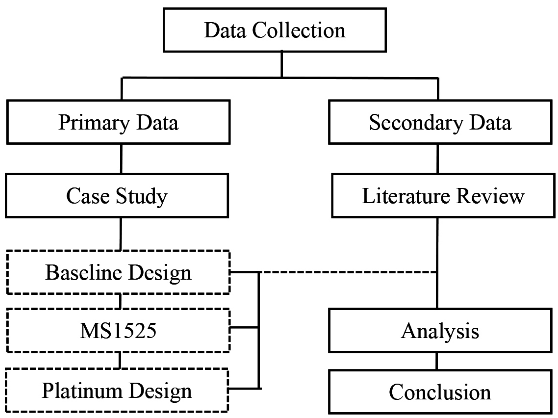

Figure 1: Overall research structure
(Source: Ismail & Zainonabidin, 2016)

4.0 RESULTS AND DISCUSSIONS

4.1 Analysis of Overall Transfer Thermal Value (OTTV) on 4G11 Tower of Ministry of Women Family and Community Development, Lot 4G11, Putrajaya, Malaysia.

4G11 Tower is a high-rise office for Ministry of Women Family and Community Development. Designed by prominent Malaysian architect Hijjas Kasturi, this 38-storey office block is the testament of national pride. Located at the heart of Precinct 4, Putrajaya with other 3 office towers, 4G11 Tower creates a vista that frames the nation's own Perdana Putra, the Prime Minister's Department Complex. This assessment investigates the probability of achieving lowest OTTV score possible for high-rise office building. LEO Building currently holds the lowest OTTV scores of 31.4 W/m². Specifications for Baseline Building Design are as follows;

i) External wall color - white spray paint.
ii) External wall construction - 25mm precast concrete panels with (U-value of 0.80).
iii) Glazing- laminated double glazing (8.76mm thick).

The main purpose of this exercise is to upgrade the existing building envelope provided that the architectural appearance of the building is not compromised. The suggested methods are by reducing the U-value and Shading Coefficient (SC) of the glass as shown in Table 1. Next is by improving Window-to-Wall Ratio (WWR) of the building envelope as shown in Table 2 and 3. In order to achieve maximum efficiency and based on the factors above, Platinum Design has proposed an estimated 30% of spandrel glass with the same appearance to replace the existing material specifications.

Table 1: Proposed glazing material for the Building Envelope

Design	Baseline	MS1525	Platinum
Glass Types	Laminated double glazing	Monolithic glass	Insulating glass
Thickness	8.76mm	12mm	28mm
Shading Coefficient	0.70	0.41	0.40
U-value (W/m²K)	5.1	3.8	1.3
Colour	Blue-green	Arctic Blue	Blue-Green
Visible Light Transmittance (VLT)	0.47	0.39	0.47

(Source: Zainonabidin & Ismail, 2015)

Table 2: Window to Wall Ratio of South and North Facade

	South Facade			North Façade		
	Baseline	**MS 1525**	**Platinum**	**Baseline**	**MS 1525**	**Platinum**
Total Facade Area	6,332.38 m²			2,684.55 m²		
With Shading Devices	2,535.40 m²		1,774.78 m²	1,679.49 m²		1,175.64 m²
	73.06 m²		51.14 m²	52.88 m²		37.02 m²
Without Shading Devices	1,380.74 m²		966.52 m²	415.02 m²		290.51 m²
Total Window Area	3,989.20 m²		2,792.44 m²	2,147.39 m²		1,503.17 m²
Spandrel Glass	-		1,196.76 m²	-		644.22 m²
Window to Wall Ratio (WWR)	0.63		0.44	0.80		0.56

(Source: Zainonabidin & Ismail, 2015)

Table 1 shown the selection of glazing material for maximum efficiency. While Table 2 shown that the total façade area is 2,684.55 m² for north façade and 6,332.38 m² for south façade. However, Window-to-Wall Ratio of north façade has been reduced from 0.80 to 0.56 while Window-to-Wall Ratio (WWR) of south façade has been reduced from 0.63 to 0.44 for Platinum Design. The reduction of Total Window Area has been replaced with 30% spandrel glass of 644.22 for north and 1196.76m² for south façade.

Table 3: Window to Wall Ratio of East and West Facade

<table>
<tr><th rowspan="2"></th><th colspan="3">East Facade</th><th colspan="3">West Facade</th></tr>
<tr><th>Baseline</th><th>MS 1525</th><th>Platinum</th><th>Baseline</th><th>MS 1525</th><th>Platinum</th></tr>
<tr><td>Total Facade Area</td><td colspan="3">7,077.16 m²</td><td colspan="3">7,077.16 m²</td></tr>
<tr><td rowspan="2">With Shading Devices</td><td colspan="2">1,795.68 m²</td><td>1,256.98 m²</td><td colspan="2">1,795.68 m²</td><td>1,256.98 m²</td></tr>
<tr><td colspan="2">118.57 m²</td><td>83.00 m²</td><td colspan="2">118.57 m²</td><td>83.00 m²</td></tr>
<tr><td>Without Shading Devices</td><td colspan="2">1,306.17 m²</td><td>914.32 m²</td><td colspan="2">1,306.17 m²</td><td>914.32 m²</td></tr>
<tr><td>Total Window Area</td><td colspan="2">3,220.42 m²</td><td>2,254.29 m²</td><td colspan="2">3,220.42 m²</td><td>2,254.29 m²</td></tr>
<tr><td>Spandrel Glass</td><td colspan="2">-</td><td>966.13m²</td><td colspan="2">-</td><td>966.13m²</td></tr>
<tr><td>Window to Wall Ratio (WWR)</td><td colspan="2">0.46</td><td>0.32</td><td colspan="2">0.46</td><td>0.32</td></tr>
</table>

(Source: Zainonabidin & Ismail, 2015)

Table 3 shown that the total façade area is 7,077.16 m² for east and west façade. Window-to-Wall Ratio (WWR) between Baseline Design and MS1525 Design remain unchanged. However, Window-to-Wall Ratio of east and west façade have been reduced from 0.46 to 0.32 for Platinum Design. The reduction of Total Window Area has been replaced with 30% spandrel glass of 966.13m² for east and west façade.

4.2 Comparison of Overall Transfer Thermal Value (OTTV) Between Baseline Design, MS1525 Design and Platinum Design

Table 4 shown that the comparison of Overall transfer Thermal Value (OTTV) in between Baseline Design, MS1525 Design and Platinum Design.

Table 4: Summary of Overall Transfer Thermal Value (OTTV) Formula

[15 α (1-WWR)Uw] + [6(WWR)Uf] + [194 x CF x WWR x SC]		
[15 α (1-WWR)Uw]	[6(WWR)Uf]	[194 x CF x WWR x SC]
Heat conduction through walls (Constant value 15.00)	Heat conduction through windows (Constant value 6.00)	Solar radiation through windows (Constant value 194.00)

Summary of Overall Transfer Thermal Value (OTTV)

	Baseline Design	**MS1525 Design**	**Platinum Design**
Glazing Type	Laminated double glazing	Monolithic glass	Insulating glass
Thickness	8.76 mm	12 mm	28 mm
Colour	Blue-green	Arctic Blue	Blue-Green
	Variable 1 - U-value		
U-value (W/m²K)	5.1	3.8	1.3
	Variable 2 - Shading Coefficient (SC)		
Shading Coefficient (SC)	0.70	0.41	0.40

Visible Light Transmittance (VLT)	0.47	0.39	0.47
	Variable 3 – Window-to-Wall Ratio (WWR)		
(WWR) North	0.80	0.80	0.56
(WWR) South	0.63	0.63	0.44
(WWR) East	0.46	0.46	0.32
(WWR) West	0.46	0.46	0.32
Spandrel glass	-	-	30%
OTTV	**77.43 Wm²**	**48.45 Wm²**	**28.43 Wm²**

The result from OTTV assessment indicates the score for Baseline Design is 77.43 Wm², MS 1525 is 48.45 Wm² and Platinum Design is 28.43 Wm².

4.2.1 Baseline Design

For Baseline Design, the OTTV score is 77.43 Wm², well over the mandatory compliance score of 50.00 Wm² for certification. The glazing material for the existing building is blue-green laminated double glazing with 8.76mm thick. The U-value of the glazing is 5.1 W/m²K with 0.70 Shading Coefficient (SC) and Visible Light Transmittance (VLT) of 0.47.

4.2.2 MS1525 Design

For MS1525 Design, the OTTV score is 48.45 Wm² It is in compliance of 50.00 Wm² score for certification. The glazing material proposed is Pilkington Eclipse Advantage™ arctic-blue monolithic with 12.00mm thick. The U-value of the glazing is 3.8 W/m²K with 0.41 Shading Coefficient (SC) and Visible Light Transmittance (VLT) of 0.39.

4.2.3 Platinum Design

For Platinum Design, the OTTV score is 28.43 Wm^2 It is in compliance of 50.00 Wm^2 for certification. The glazing material proposed is Pilkington Eclipse Advantage™ blue-green insulating glass with 28.00mm thick. The colour selection is same with the existing Baseline Design. The insulating glass is 6.00mm thick sandwich with 16.00mm filled with argon gas cavity. The U-value of the glazing is 1.3 W/m^2K with 0.40 Shading Coefficient (SC) and Visible Light Transmittance (VLT) of 0.47, same with the existing Baseline Design.

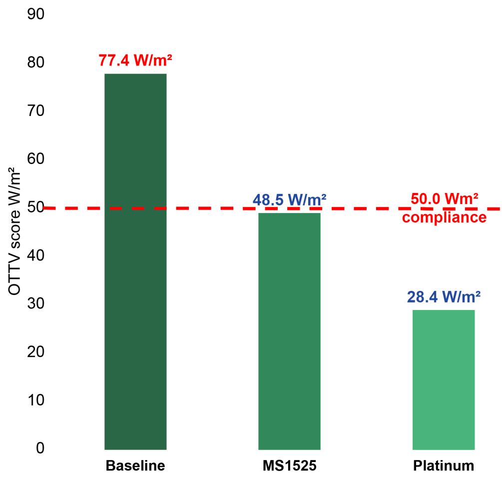

Figure 2: Comparison of OTTV score between Baseline, MS1525 and Platinum Design
(Source: Ismail & Zainonabidin, 2016)

The Baseline Design is using laminated double glazing glass while MS1525 Design is using monolithic glass. Glazing material is changed to Pilkington Eclipse Advantage™ arctic-blue glass. This helps to reduce the U-value from 5.1Wm^2/k to 3.8Wm^2/k. The material is better heat insulator but the colour scheme also different compared to the existing colour of blue-green. While lower U-value helps to reduce heat gain into the building, it also reduces the Visible Light Transmittance (VLT) from 0.47 to 0.39, thus will reduce the percentage of visible light passing through the building which will make the interior space appear darker compared to existing condition. Shading Coefficient (SC) also decrease from 0.70 to 0.41. The LEO Building of the Ministry of Energy, Water and Communication is currently the most energy efficient building with OTTV score of 31.4 Wm². Therefore, based on the results of this exercise, it is proven that OTTV can be major influence towards energy efficiency. The 4G11 Tower proposed Platinum Design has eclipsed The LEO Building by 10% to be more energy efficient with comparative OTTV score of 28.43 Wm² to 31.4 Wm².

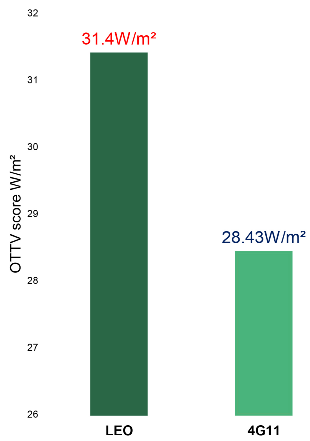

Figure 3: Comparison of OTTV score between The (LEO) and 4G11 Tower
(Source: Ismail & Zainonabidin, 2016)

Insulated glass is proposed in Platinum Design to achieve maximum efficiency. In order to maintain the similar visual appearance and architectural features of existing building, the same colour blue-green of Pilkington Eclipse Advantage™ is installed. The U-value drastically changed from 3.8Wm²/k to 1.2Wm²/k because the principle function of insulating glass itself. With 6mm thick glass sandwiched with argon filled gas, it helps to reduce heat gain considerably. Visible Light Transmittance (VLT) is changed to the existing Baseline Design 0.47. This will make more visible light passing through the building which will make the interior space brighter compared to existing condition. Shading Coefficient (SC) shows a slight decrease from 0.41 to 0.40.

The Window to Wall Ratio (WWR) is reduced from 0.8 to 0.56 for north façade, 0.63 to 0.44 for south façade and 0.46 to 0.32 to east and west façade. Note that the reduction of Total Window Area has been replaced with 30% spandrel glass for north façade 644.22 m², south façade 1,196.76 m², east façade 966.13 m² and west façade 966.13 m² respectively. Spandrel glass helps to further reduce the overall heat gain into the building.

5.0 CONCLUSIONS AND RECOMMENDATIONS

OTTV has proven to be huge contributing tools towards energy efficiency. Based on OTTV assessment result, it is found that improving OTTV does not only reduce heat gain into the building but in a bigger picture, it is also a cost-saving benefactor in the long term. The three variables of U-Value, Shading Coefficient (SC), and Window-to-Wall Ratio (WWR) in OTTV components helps to reduce the existing score of Baseline Design 77.43 Wm² to Platinum Design 28.43 Wm². This assessment proves that retrofitting existing high-rise office is possible by using a thorough and calculated approach with 4G11 Tower as the precedent. It is plausible that OTTV is lengthy calculation tool and only applicable for building envelope solely. Then it is argued that OTTV also limiting design expression but on the other hand, it exercises the capabilities of professionals moderating between design expressions and building economics. Education and training of professionals such as architects and engineers on OTTV assessment will help to further understanding thus will improvise the limitations of OTTV formula. Promoting the use of software on OTTV also will help to reduce error for calculation and revising purpose. Hopefully, the building professionals are aware the importance of building efficiency and embrace the holistic approach to sustainability in planning, design, and construction phase. In general, the study has demonstrated that the government's policy towards green building initiatives and aspirations of making Putrajaya as Sustainable Development Administrative Centre by 2025 for the future and greener Malaysia can be turned into a reality.

ACKNOWLEDGEMENT

I am grateful to Allah The Most Gracious and Most Merciful for a gift that granted me strength and knowledge. My first and foremost gratitude are to my parents, Hj. Ismail Hj. Ahmad and Fatimah Hj. Mohd. Yusof, and my family. I also would like to express my gratitude to my mentor, Ar. Hj. Azman Zainonabidin for his continuous encouragement, sincerity and professionalism. I could not ask for a better mentorship. Last but not least, thank you to others who involved direct or indirectly in this writing process.

REFERENCES

ANSI/ASHRAE/IES *Standard 90A-1980, Energy Conservation in New Building Design,* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1980.

Building Deartment (2014). *Design and Construction Requirements for Energy Efficiency of Residential Buildings* Hong Kong Retrieved fromhttp://www.bd.gov.hk/english/documents/pnap/APP/APP156.pdf

Department of Standards Malaysia (2007), MS1525:2007 *Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings;*

Economic Planning Unit. (2015). *Eleventh Economic Plan 2016 - 2020.* Putrajaya, Malaysia: Economic Planning Unit, Prime Minister's Department, Malaysia.

Green Building Index Sdn. Bhd. (2011), *Non-Residential New Construction (NRNC): Design Reference Guide & Submission Format;* Kuala Lumpur, Malaysia.

Hui, S. C. (1997). *Overall Thermal Transfer Value (OTTV): How to Improve Its Control in Hong Kong.* Paper presented at the In Proc. of the One-day Symposium on Building, Energy and Environment (Vol. 16, pp. 12-1).

Ministry of Energy, Telecommunications and Posts (1989). *Guidelines for Energy Efficiency in Buildings-1989.*Kuala Lumpur, Malaysia.

Pilkington. (2010). *Pilkington Glass Handbook 2010*. In NSG Group Flat Glass Business (Ed.).

R. Saidur, M. Hasanuzzaman, M.M. Hasan and H.H. Masjuki (2009). *Overall Thermal Transfer Value of Residential Buildings in Malaysia,* Journal of Applied Sciences 9(11) 2130-2136, Malaysia.

Zainonabidin, A., & Ismail, A. A. (2015). *Improving Overall Thermal Transfer Value of Office Tower Building in Malaysia. Case Study: Ministry of Women Family and Community Development, Lot 4G11, Putrajaya.* Paper presented at the Go Green 2015: International Postgraduate Conference on Global Green Issues. (Vol. 1 pp. 191 - 199)