CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this section of the dissertation, a sample calculation and the summary result obtained from calculation and stimulation for ETTV, cooling load and also E_c using the methodologies described in Chapter 3. These results obtained will then be tabulated, discussed and express in graphical presentation to study the relationship between the two values.

4.2 ENVELOPE THERMAL TRANSMITTANCE VALUE (ETTV) RESULT

4.2.1 Summary of Envelope Area

Based on the building design, the total envelope area is computed based on methodology presented in Chapter 3.3.1. The areas are tabulated in accordance to the facade orientation in relative to the floor and are differentiate between wall areas (AW), louver area (AL) and window / glass areas (AG). This exercise is important for the later stage calculation to compute the total ETTV value. Based on this tabulated data as well, the window to wall ratio can be easily ascertain for further comparison.

Table 4.1: Summary of Envelope Area

FACADE ORIENTATION	LEVEL 1		LEVEL 2		LEVEL 3		LEVEL 4		LEVEL 5		LEVEL 6		TOTAL		OVERALL TOTAL
NORTH-EAST	**AW1**	54.51											**AW1**	54.51	
											AW2	11.50	**AW2**	11.50	
	AW3	11.10	**AW3**	82.80	**AW3**	60.65	**AW3**	31.14	**AW3**	19.80	**AW3**		**AW3**	205.49	
			AW5	4.40									**AW5**	4.40	
							AW6	25.49	**AW6**	42.40	**AW6**	21.60	**AW6**	89.49	
					AW9	23.65							**AW9**	23.65	
							AW10	28.70					**AW10**	28.70	
			AW11	7.26									**AW11**	7.26	
	AG1		**AG1**	18.00	**AG1**	43.50	**AG1**	87.50	**AG1**	76.70	**AG1**	162.00	**AG1**	387.70	
	AG3		**AG3**		**AG3**		**AG3**	17.30	**AG3**	16.40	**AG3**		**AG3**	33.70	
	AG4		**AG4**		**AG4**		**AG4**	40.10	**AG4**	47.20	**AG4**		**AG4**	87.30	
											AL	38.70	**AL**	38.70	**972.4**
SOUTH-WEST	**AW1**	109.40	**AW1**	181.40	**AW1**	178.30	**AW1**	214.70	**AW1**	2.40	**AW1**		**AW1**	686.20	
											AW2	2.30	**AW2**	2.30	
			AW5	4.40									**AW5**	4.40	
			AW6	14.20	**AW6**	14.20	**AW6**	17.34	**AW6**	2.30	**AW6**	5.56	**AW6**	53.60	
											AL	22.80	**AL**	22.80	
	AG1	114.00	**AG1**	18.00	**AG1**	27.40	**AG1**	12.30	**AG1**	23.30	**AG1**	37.60	**AG1**	232.60	
	AG2		**AG2**	25.03	**AG2**	25.03	**AG2**	25.03	**AG2**		**AG2**		**AG2**	75.09	
	AG3		**AG3**		**AG3**		**AG3**	5.10	**AG3**	4.00	**AG3**		**AG3**	9.10	
	AG4		**AG4**		**AG4**		**AG4**	9.20	**AG4**	2.50	**AG4**		**AG4**	11.70	**1097.8**

Table 4.1: Summary of Envelope Area (Cont.)

FACADE ORIENTATION	LEVEL 1		LEVEL 2		LEVEL 3		LEVEL 4		LEVEL 5		LEVEL 6		TOTAL		OVERALL TOTAL
SOUTH-EAST	**AW1**	129.12	**AW1**	114.56	**AW1**	108.39	**AW1**	133.48					**AW1**	485.55	
											AW2	9.30	**AW2**	9.30	
			AW3	61.62	**AW3**	69.97	**AW3**	25.20					**AW3**	156.79	
			AW5	3.80	**AW5**	3.80							**AW5**	7.60	
			AW6	2.64	**AW6**	2.64	**AW6**	5.95	**AW6**	3.38			**AW6**	14.61	
							AW8	5.10					**AW8**	5.10	
			AW11	7.92	**AW11**	2.64	**AW11**	38.88					**AW11**	49.44	
	AG1		**AG1**	13.80	**AG1**	12.60	**AG1**	15.56	**AG1**	12.19	**AG1**	2.60	**AG1**	56.75	
	AG2		**AG2**	4.42	**AG2**	4.42	**AG2**	2.94	**AG2**		**AG2**		**AG2**	11.78	
	AG3		**AG3**		**AG3**		**AG3**	5.00	**AG3**	4.50	**AG3**		**AG3**	9.50	
	AG4		**AG4**		**AG4**		**AG4**	8.70	**AG4**	7.90	**AG4**		**AG4**	16.60	
	AL		**AL**		**AL**		**AL**		**AL**	10.50	**AL**	39.50	**AL**	50.00	**873.0**
NORTH-WEST	**AW1**	140.50	**AW1**	151.17	**AW1**	157.14	**AW1**	181.70	**AW1**		**AW1**		**AW1**	630.51	
											AW2	4.80	**AW2**	4.80	
			AW3	6.73	**AW3**	6.49							**AW3**	13.22	
							AW4	34.70	**AW4**	30.00			**AW4**	64.70	
			AW5	3.80	**AW5**	3.80							**AW5**	7.60	
			AW6	10.45	**AW6**	10.97	**AW6**	10.74			**AW6**	7.60	**AW6**	39.76	
							AW7	5.80					**AW7**	5.80	
			AW11	2.88			**AW11**	2.64					**AW11**	5.52	
	AG1	62.94	**AG1**	10.60	**AG1**	30.40	**AG1**		**AG1**		**AG1**	35.90	**AG1**	139.84	
	AG2		**AG2**	20.26	**AG2**	21.19	**AG2**	22.74	**AG2**		**AG2**		**AG2**	64.19	
	AG4		**AG4**		**AG4**		**AG4**		**AG4**		**AG4**		**AG4**	0.00	**975.9**

Taking the NorthWest façade orientation as example, the total envelope area can be divided into 3 areas namely wall, glass and louver. For wall, there are 8 type of wall involved with the corresponding total area; AW1 (54.51 m^2), AW2 (11.50 m^2), AW3 (205.49 m^2), AW5 (4.40 m^2), AW6 (89.49 m^2), AW9 (23.65 m^2), AW10 (28.70 m^2) and AW11 (7.26 m^2). Glass areas consist of 3 types of glasses; AG1 (387.70 m^2), AG2 (33.70 m^2) & AG4 (87.30 m^2). Lastly for the louvers area there is only one type of louvers, AL (38.70 m^2). By summing up the above area based on the type of envelope, the total area for NorthWest envelope for the case study is obtained as 972.4 m^2 while the total area for wall is 425 m^2 and total area for glass is 547.1 m^2. By dividing the total area of glass with the total area for NorthWest façade, the Window to Wall Ratio (WWR) can be obtained as 0.56 using Equation 3.1.

This is done similarly to all other facades of the building to obtain the total envelope area for the building. Using the above data, WWR for each facade orientation and overall WWR was found to be as follows:

Table 4.2: Summary of Window to Wall Ratio (WWR) for Different Orientation

Orientation	WWR
North-East	0.56
South-West	0.30
South-East	0.11
North-West	0.21
Overall	0.29

It shown from the table that NorthWest façade has the most glass area and the average glass area of the case study building stands at 29%. It is also shown that AG1, glass area using 13.52 mm Sunergy Clear Glass has the most impact of all glasses type used for the case study building. The significance of WWR can be established as a guide to having a smaller ETTV. This can be done by determining the WWR for each façade and by planning the building orientation to avoid west and east facing façade for the façade with the most glass area.

4.2.2 Summary of U-Value Result

The building design is a mixture of various walls and fenestrations type with different composition. To ascertain the ETTV, all type of walls and fenestrations shall be tabulated and the composition of each wall and fenestration determined. By doing so, the U-Value of all wall type and fenestration can be calculated as presented in Chapter 3.3.2.

From the building data, it was found that there are 11 wall type and 27 fenestration type with 7 of which using 13.52 mm Sunergy Clear Glass, 3 using 12mm Clear Glass, 6 using 6 mm Asahimas Green Glass, 5 using 13.52 mm Translucent Glass, 5 using 13.52 mm Opaque Glass and 1 using 6 mm Asahimas Frosted Green Glass. Calculation for all walls U-Value can be done as per the following calculation sample.

Taking a wall example; W2, the U-Value can be calculated as follows:

Table 4.3: Sample U-Value Calculation

	COMPONENT	**b**	**K**	**DENSITY**	**R**	**U**	**AREA DENSITY**
	UNIT	**mm**	**W/m.K**	**Kg/m^3**	**m^2.K/W**	**W/(m^2.^{O}K)**	**KG/m^2**
	EXTERNAL	-	-	-	0.044	-	-
1	25mm Cement Plaster	25	0.533	1568	0.04690	-	39.2
2	200mm Precast RC Wall	200	1.442	2400	0.139	-	480
3	25mm Cement Plaster	25	0.533	1568	0.04690	-	39.2
4	125mm Air Gap	-	-	-	0.160	-	-
5	Aluminum Composite Panel	4	211	2672	0.000	-	10.688
	INTERNAL	-	-	-	0.120	-	-
Total R	-	-	-	-	0.557	**1.80**	569.1

Using Equation 3.3 the total R value , 0.557 m^2.K/W is obtained. Using Equation 3.2, U-Value of W2, 1.80 W/m^2.^{o}K is obtained. These values shall be used for ETTV calculation and also the cooling load calculation.

As for the glass U-Value, no calculation is needed as it is the performance of the glass received from the glass manufacturer. Using the same methodology as shown above, the U-Value for all wall and fenestrations are summarized as follows:

Table 4.4: Summary of U-Value Calculation for Walls & Fenestration

Item	**Wall/Fenestration Description**	**U-Value (W/m$^{2.\,0}$K)**
W1	200 mm Brick wall with 25 mm cement plaster	1.978
W2	200 mm RC slab with 25 mm cement plaster + 125 mm Air Gap + Aluminum Composite Panel	1.80
W3	200mm RC wall with 25 mm cement plaster	2.521
W4	13.52 mm thk. Opaque Glass +50 mm Rock Wool+ 150 mm Air Gap +15 mm thk Cement Plaster Board	0.508

Table 4.4: Summary of U-Value Calculation for Walls & Fenestration (Cont.)

Item	Wall/Fenestration Description	U-Value ($W/m^{2.0}K$)
W5	13.52 mm thk. Clear Glass + 90 mm Air Gap + Aluminum Back Panel + 50 mm thk. Rockwool + 300 mm Rc beam	0.466
W6	Aluminum Panel + Air Gap + Aluminum Panel	3.086
W7	13.52mm thk. Opaque Glass +100mm Air Gap +Aluminum Backpanel+50mm Rock Wool+75mm air gap + 300mm Wide RC Beam	0.435
W9	13.52 mm thk. Opaque glass + 150 mm air gap + 50mm Rockwool + 600 mm wide RC beam + 150 mm airgap + 600mm RC beam	0.341
W10	25 mm plaster + 150mm wide RC beam + 850 mmwide soil + 600 mm wide RC beam	0.334
W11	Aluminum Door	1.900
W12	4 mm Aluminum Composite Panel + 125 mm Air Gap + 25 mm Plaster + 200 mm Precast RC Wall + 25 mm Plaster	1.77
F1-1	13.52 mm thk. Clear Glass (6mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green)	5.3
F1-2	13.52 mm thk. Clear Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green) with 1.9 m width horizontal projection	5.3
F1-3	13.52 mm thk. Clear Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green) with 0.3 m width vertical projection (SE&SW)	5.3
F1-4	13.52 mm thk. Clear Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green) with 1.2 m width horizontal projection	5.3
F1-5	13.52 mm thk. Clear Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green) with 1.1 m width horizontal projection	5.3
F1-6	13.52 mm thk. Clear Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green) with 1.4 m width horizontal projection	5.3
F1-7	13.52 mm thk. Clear Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green) with 0.3 m width vertical projection (NE&NW)	5.3
F2-1	12 mm thk.Clear Glass at L-1	4.84
F2-2	12 mm thk. Clear Glass at L-1 with 2.3 m width horizontal projection	4.84
F2-3	12 mm thk. Clear Glass at L-1 with 2.6m width horizontal projection	4.84

Table 4.4: Summary of U-Value Calculation for Walls & Fenestration (Cont.)

Item	Wall/Fenestration Description	U-Value ($W/m^{2.0}K$)
F3-1	6 mm thk. Asahimas Green Glass	5.37
F3-2	6 mm thk. Asahimas Green Glass with 0.6 m width horizontal projection (SW)	5.37
F3-3	6 mm thk. Asahimas Green Glass with sloping horizontal projection (SW&SE)	5.37
F3-4	6 mm thk. Asahimas Green Glass with 0.6 m width horizontal projection (SE)	5.37
F3-5	6 mm thk. Asahimas Green Glass with 0.6 m width horizontal projection (NW)	5.37
F3-6	6 mm thk. Asahimas Green Glass with sloping horizontal projection (NW&NE)	5.37
F4-1	13.52 mm thk. Translucent Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 30% pos.2)	5.3
F4-2	13.52 mm thk. Translucent Glass (6 mm Sunergy Clear against pvb + 1.52mm Clear pvb + 6 mm Light Green with silk screen White 30% pos.2) with 1.9 m width horizontal projection	5.3
F4-3	13.52 mm thk. Translucent Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 30% pos.2) with 1.2 m width horizontal projection	5.3
F4-4	13.52 mm thk. Translucent Glass (6mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 30% pos.2) with 1.1 m width horizontal projection	5.3
F4-5	13.52 mm thk. Translucent Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 30% pos.2) with 1.4m width horizontal projection	5.3
F5-1	13.52 mm thk. Opaque Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 100% pos.2)	5.3
F5-2	13.52 mm thk. Opaque Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 100% pos.2) with 1.9 m width horizontal projection	5.3
F5-3	13.52 mm thk. Opaque Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 100% pos.2) with 1.2 m width horizontal projection	5.3
F5-4	13.52 mm thk. Opaque Glass (6 mm Sunergy Clear against pvb + 1.52mm Clear pvb + 6 mm Light Green with silk screen White 100% pos.2) with 1.1 m width horizontal projection	5.3
F5-5	13.52 mm thk. Opaque Glass (6 mm Sunergy Clear against pvb + 1.52 mm Clear pvb + 6 mm Light Green with silk screen White 100% pos.2) with 1.4 m width horizontal projection	5.3
F6-1	6 mm thk. Asahimas Green Frosted Glass	5.6

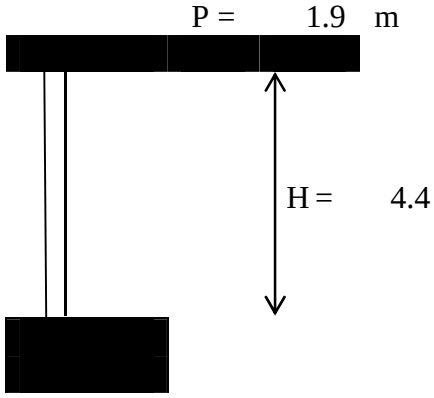
4.2.3 Summary of SC-Value Result

From the tabulation of envelope area, it was found that 13.53 mm Sunergy Clear Glass has the most impact area as it has the highest WWR ratio. Thus it is selected and will be varied in the SC-Value. The U-value will remain. The original glass performance of 13.52mm Sunergy Clear Glass is U-Value 5.3 $W/m^2.^oK$; SC-Value 0.51. As per the proposed methodology presented in Chapter 3.33, the selected glass and all the corresponding fenestration using the same glass shall be recalculated.

As F1-1 is the original glass performance without overhang projection, the actual glass performance shall be used. For all other glass fenestration, the SC-Value for its corresponding SC based on the projection can be calculated as shown in the example below using Equation 3.4. Taking F1-2 as example, the calculation of the corresponding SC-Value for F1-2 is as follows:

SC1= 0.2 (ORIGINAL SC VALUE OF GLASS)
SC2:

Facade:
SW(L5-Clear)(Grid 6-5,17-18)
(F1-2)
(INTERNAL SECTIONAL ELEV; - 2)



H = 4.4 m R = (P/H) = 0.43

P = 1.9 m

Interpolating from table in handbook on energy conservation in buildings and buildings services for various projection for different orientation.

From Table 13: R= 0.43

$$\left(\frac{0.43 - 0.4}{0.5 - 0.4}\right)(0.6981 - 0.7413) + 0.7413$$

S_{C2} = 0.728

$SC = SC_1 \times SC_2 = 0.20 \times 0.728 = \mathbf{0.146}$

The following is the summary of the SC-Value for all calculated corresponding fenestrations using 13.52 mm Sunergy Clear Glass based on the variation presented in Chapter 3.5 Table 3.2. The value in bold presented in Table 4.4 is the predetermined SC-Value of the glass using 13.52 mm Sunergy Clear Glass based on the variation presented in Chapter 3.5, Table 3.2.

Table 4.5: Summary of SC-Value Calculation for 13.52 mm Sunergy Clear Glass

SC-Value	**0.2**	**0.4**	**0.51**	**0.6**	**0.8**
F1-1	0.2	0.4	0.51	0.6	0.8
F1-2	0.146	0.29	0.371	0.437	0.582
F1-3	0.122	0.244	0.311	0.366	0.489
F1-4	0.16	0.32	0.408	0.481	0.641
F1-5	0.167	0.334	0.425	0.501	0.667
F1-6	0.157	0.314	0.4	0.471	0.628
F1-7	0.126	0.253	0.322	0.379	0.505
F1-8	0.128	0.255	0.325	0.383	0.51

Based on the above data, the ETTV will be calculated with each set of glass for each variation of the SC-Value from 0.2 to 0.8 to obtain the relationship and significant of glass performance toward ETTV and E_c consumption.

4.2.4 Summary of ETTV Result

Based on the methodology presented in Chapter 3.3.4, the ETTV value can be calculated using Equation 3.13. Taking an example using 13.52 mm Clear Glass 1 with U-Value of 5.3 $W/m^2.^oK$ and variation of SC-Value of 0.2, the corresponding ETTV calculated was 39.89 W/m^2. This is done by first determining the ETTV for each façade orientation as per the sample calculation below. The opaque wall portion and fenestration portion of Equation 3.13 is tabulated separately for easier calculation as shown in the sample calculation.

Table 4.6: Sample ETTV Calculation for North West Façade

Façade Orientation : North West

Opaque Walls

S/N	Brief Description	AW	UW	11.9 x AW x UW
W1	200mm Brick wall with 25mm cement plaster	631	1.98	14,850.3
W2	200mm RC wall with 25mm cement plaster + 125mm Air Gap + Aluminum Composite Panel	5	1.36	80.9
W3	200mm RC wall with 25mm cement plaster	8.12	2.52	243.6
W4	13.52mm thk. Opaque Glass +50mm Rock Wool+ 150mm Air Gap +15mm thk Cement Plaster Board	60.35	0.55	397.7
W6	Aluminum Panel + Air Gap + Aluminum Panel	40	1.05	501.6
W7	13.52mm thk. Opaque Glass +100mm Air Gap +Aluminum Backpanel+50mm Rock Wool+75mm air gap + 300mm Wide RC Beam	6	0.39	27.6
Subtotal		754.36		16,125.1

Fenestration

S/N	Brief Description	AF	UF	SC (SC1x SC2)	3.37 x Af x Uf	210.9 x Af x SC x CF (CF =1.03)
F2-2	12mm thk.Clear Glass with over-hang (L1)	62.94	4.84	0.68	1026.6	9,247.7
F1-1	13.52mm thk. Clear Glass	24.22	5.3	0.20	432.6	1,052.2
F1-7	13.52mm thk. Clear Glass with Vertical louvers (L-6)	35.90	5.3	0.13	641.2	985.2
F1-8	13.52mm thk. Clear Glass with over-hang (L-5)	3.60	5.3	0.13	64.3	99.8
F3-5	6mm thk. Asahimas Green Glass with over-hang (L-4)	19.26	5.37	0.57	348.5	2,369.3
F3-6	6mm thk. Asahimas Green Glass with louver	10.44	5.37	0.30	188.9	669.2
F3-1	6mm thk. Asahimas Green Glass	34.3	5.37	0.62	620.7	4,619.5
F4-6	13.52mm thk. Translucent Glass with over-hang (L-5)	1.05	5.3	0.29	18.8	66.9
Subtotal		191.71			3341.7	19,109.9

Gross Area of External Walls (A_o)	:	946.07	m2
Gross Heat Gain	:	38,576.6	W
ETTV = $\frac{\text{Gross Heat Gain}}{\text{Gross Area}}$	:	**40.8**	W/m^2

Taking the sum of area involves for both opaque and fenestration walls give the gross area of external walls, $A_{0.}$ By multiplying the corresponding ETTV for the particular façade with the A_0 gives the weightage values for this North West façade of 39391.69 W/m^2 for the overall ETTV value calculation. This is done similarly for all other façades.

Table 4.7: Sample ETTV Calculation for North East Façade

Façade Orientation : North East

Opaque Walls

S/N	Brief Description	AW	UW	11.9 x AW x UW
W1	200mm Brick wall with 25mm cement plaster	37.93	1.98	892.7
W2	200mm RC wall with 25mm cement plaster + 125mm Air Gap + Aluminum Composite Panel	12	1.36	194.1
W3	200mm RC wall with 25mm cement plaster	263.2	2.52	7,897.9
W5	13.52mm thk. Clear Glass + 90mm Air Gap + Aluminum Back Panel + 50mm thk. Rock wool + 300mm Rc beam (sectional elev; 4)	4	0.50	24.0
W6	Aluminum Panel + Air Gap + Aluminum Panel	89	1.05	1,116.0
W9	13.52mm thk. Opaque glass + 150mm air gap + 50mm Rock wool + 600mm wide RC beam + 150mm airgap + 600mm RC beam	24	0.36	103.1
W10	25mm plaster + 150mm wide RC beam + 850mmwide soil + 600mm wide RC beam	29	0.33	115.1
W11	Aluminum Door	8.18	1.42	138.0
W12	4mm Aluminum Composite Panel + 125mm Air Gap + 25mm Plaster + 200mm Pre cast RC Wall + 25mm Plaster	39	1.00	462.9
Subtotal		506.3		10,943.9

Fenestration

S/N	Brief Description	AF	UF	SC (SC1x SC2)	3.37 x Af x Uf	210.9 x Af x SC x CF (CF =0.97)
F1-5	13.52mm thk. Clear Glass with over-hang (L-4)	87.5	5.3	0.17	1562.8	2,986.5
F1-6	13.52mm thk. Clear Glass with over-hang (L-5)	76.7	5.3	0.16	1369.9	2,463.6
F1-7	13.52mm thk. Clear Glass with over-hang (L-6)	162	5.3	0.13	2893.5	4,186.9
F1-1	13.52mm thk. Clear Glass	61	5.3	0.2	1089.5	2,495.8
F4-4	13.52mm thk. Translucent Glass with over-hang (L-4)	17.3	5.3	0.38	309.0	1,358.1
F4-5	13.52mm thk. Translucent Glass with over-hang (L-5)	16.4	5.3	0.37	292.9	1,229.2
F5-4	13.52mm thk. Opaque Glass with overhang (L4)	40.1	5.3	0.27	716.2	2,189.8
F5-5	13.52mm thk. Opaque Glass with overhang (L5)	47.2	5.3	0.25	843.0	2,461.0
Subtotal		508.2			9077.0	19,370.9

Gross Area of External Walls (A_o) : 1014.53 m2

Gross Heat Gain : 39,391.7 W

ETTV = $\frac{\text{Gross Heat Gain}}{\text{Gross Area}}$: **38.8** W/m^2

Table 4.8: Sample ETTV Calculation for South West Façade

Façade Orientation : South West

Opaque Walls

S/N	Brief Description	AW	UW	11.9 x AW x UW
W1	200mm Brick wall with 25mm cement plaster	701.5	1.98	16,509.5
W2	200mm RC slab with 25mm cement plaster + 125mm Air Gap + Aluminum Composite Panel	2	1.36	32.4
W5	13.52mm thk. Clear Glass + 90mm Air Gap + Aluminum Back Panel + 50mm thk. Rockwool + 300mm Rc beam (internal elev; 2)	7.3	0.50	43.8
W6	Aluminum Panel + Air Gap + Aluminum Panel	54	1.05	677.1
W12	4mm Aluminum Composite Panel + 125mm Air Gap + 25mm Plaster + 200mm Precast RC Wall + 25mm Plaster	23	1.00	273.0
Subtotal		787.8		17,535.7

Fenestration

S/N	Brief Description	AF	UF	SC (SC1x SC2)	3.37 x Af x Uf	210.9 x Af x SC x CF (CF =1.06)
F2-1	12mm thk. Clear Glass with over-hang (L-1)	114	4.84	0.60	1859.4	15,410.2
F1-2	13.52mm thk. Clear Glass with over-hang (L-5)	23.3	5.3	0.15	416.2	757.9
F1-3	13.52mm thk. Clear Glass with over-hang (L-6)	37.6	5.3	0.12	671.6	1,026.6
F1-1	13.52mm thk. Clear Glass	63.8	5.3	0.20	1139.5	2,852.5
F3-2	6mm thk. Asahimas Green Glass with over-hang (L-4)	19.9	5.37	0.56	360.1	2,476.2

S/N	Brief Description	AF	UF	SC (SC1x SC2)	3.37 x Af x Uf	210.9 x Af x SC x CF
F3-3	6mm thk. Asahimas Green Glass with louver	15.39	5.37	0.27	278.5	945.6
F3-1	6mm thk. Asahimas Green Glass	39.71	5.37	0.62	718.6	5,503.9
F4-2	13.52mm thk. Translucent Glass with over-hang (L5)	4	5.3	0.33	71.4	299.3
F4-1	13.52mm thk. Translucent Glass	5.1	5.3	0.46	91.1	524.5
F5-1	13.52mm thk. Opaque Glass	9.2	5.3	0.32	164.3	658.1
F5-2	13.52mm thk. Opaque Glass with overhang (L5 - Gri 6-5/17-18)	2.5	5.3	0.23	44.7	130.1
Subtotal		334.5			5815.5	30,585.0

Gross Area of External Walls (A_o) : 1122.3 m2

Gross Heat Gain : 53,936.2 W

ETTV = $\frac{\text{Gross Heat Gain}}{\text{Gross Area}}$: **48.1** W/m^2

Table 4.9: Sample ETTV Calculation for South East Façade

Façade Orientation : South East

Opaque Walls

S/N	Brief Description	AW	UW	11.9 x AW x UW
W1	200mm Brick wall with 25mm cement plaster	476.4	1.98	11,211.8
W2	200mm RC slab with 25mm cement plaster + 125mm Air Gap + Aluminum Composite Panel (sectional elev; 2)	9	1.36	145.6
W3	200mm RC wall with 25mm cement plaster (Sectional Elev; 2)	157	2.52	4,710.8
W5	13.52mm thk. Clear Glass + 90mm Air Gap + Aluminum Back Panel + 50mm thk. Rockwool + 300mm RC beam	8	0.50	48.0
W6	Aluminum Pnel + Air Gap + Aluminum Panel	16.76	1.05	210.2
W8	13.52mm Clear Glass + 100mm Air Gap + Aluminum Back Panel + 50mm thk. Rock wool + 75mm Air Gap + 300mm wide RC Beam	5	0.39	23.0
W11	Aluminum Door	34.86	1.42	588.1
W12	4mm Aluminum Composite Panel + 125mm Air Gap + 25mm Plaster + 200mm Precast RC Wall + 25mm Plaster	50	1.00	593.5
Subtotal		757		17,531.0

Fenestration

S/N	Brief Description	AF	UF	SC (SC1x SC2)	3.37 x Af x Uf	211 x Af x SC x CF (CF =0.98)
F1-1	13.52mm thk. Clear Glass	40.94	5.3	0.20	731.2	1,692.3
F1-4	13.52mm thk. Clear Glass with over-hang (L-5)	8.91	5.3	0.16	159.1	295.0
F3-4	6mm thk. Asahimas Green Glass with overhang (L4)	2.37	5.37	0.59	42.9	290.0
F3-3	6mm thk. Asahimas Green Glass with louver	2.50	5.37	0.27	45.2	141.8
F3-1	6mm thk. Asahimas Green Glass	9.79	5.37	0.62	177.2	1,254.5
F4-1	13.52mm thk. Translucent Glass	3.93	5.3	0.46	70.2	373.6
F4-3	13.52mm thk. Translucent Glass with over-hang (L-5)	4.5	5.3	0.37	80.4	342.6
F5-1	13.52mm thk. Opaque Glass	11.93	5.3	0.32	213.1	789.0
F5-3	13.52mm thk. Opaque Glass with overhang (L5)	11.13	5.3	0.26	198.8	589.5
F6-1	6mm thk. Asahimas Green Frosted Glass	0.84	5.6	0.56	15.9	97.2
Subtotal		96.84			1733.9	5865.6

Gross Area of External Walls (A_o) : 853.857 m2

Gross Heat Gain : 25,130.6 W

ETTV = $\frac{\text{Gross Heat Gain}}{\text{Gross Area}}$: **29.4** W/m^2

Based on the calculated ETTV value for each orientation, the overall ETTV is calculated as follows using Equation 3.14:

$$\text{Overall ETTV} = \frac{\begin{array}{llllllllll} 0.00 & + & 39391.69 & + & 38576.60 & + & 53936.19 & + \\ 0.00 & + & 0.00 & + & 0.00 & + & 25130.58 & \\ 0.00 & + & 1014.53 & + & 946.07 & + & 1122.30 & + \\ 0.00 & + & 0.00 & + & 0.00 & + & 853.86 & \end{array}}{3936.76}$$

$$= \frac{157035.06}{3936.76}$$

$$= \mathbf{39.89\ W/m2}$$

Using the different SC-Value variation of 13.52mm Clear Glass, the ETTV value for each value is computed similarly. It was found that with the selected building configuration, each 0.1 drop in the SC-Value of the glass, the ETTV value decrease by 2.67. This value is rather significant as each 10% increase in the glass performance, the ETTV improve by 4.37%.

Table 4.10: Summary of ETTV Value Calculation with Different Glass SC-Value

Item	Description	ETTV Value (W/m^2)
1	13.52mm Clear Sunergy Glass 1 (U-value 5.3 & SC-Value 0.2)	39.89
2	13.52mm Clear Sunergy Glass 2 (U-value 5.3 & SC-Value 0.4)	45.20
3	13.52mm Clear Sunergy Glass 3 (U-value 5.3 & SC-Value 0.51)	48.12
4	13.52mm Clear Sunergy Glass 4 (U-value 5.3 & SC-Value 0.6)	50.50
5	13.52mm Clear Sunergy Glass 5 (U-value 5.3 & SC-Value 0.8)	55.81

However the above value is only specific to our selected case study building and may not be the representative in general for other buildings because with a different WWR ratio and building configuration, the impact will be different.

4.3 TOTAL COOLING ENERGY (E_c) CONSUMPTION RESULT

4.3.1 Total Cooling Load, E_{cl} Result

A model of the building is firstly built using the profile of building as such the wall area, window area, orientation in the E-20 program. Then based on the different performance of the glass, the model is simulated to give the required cooling load required for each air conditioned space within the building. By adding the entire calculated required cooling load gives the E_{cl} required for the development. The results obtained are tabulated as follows for each variation of the SC-Value for 13.52 mm Clear Sunergy Glass.

Table 4.11: Summary of E_{cl} Calculation with Different Glass SC-Value

Glass SC-Value	0.2	0.4	0.51	0.6	0.8
Total Cooling Load (kW)	908.70	937.50	957.20	968.40	999.50

Based on the above result obtained, it is found that with lower performance glass (glass with higher SC-Value), the cooling load require for the same space will be higher. Based on the studied building configuration, with each 0.1 SC-Value increase for the selected glass the E_{cl} increases by approximately 14.5 kW. This value is significant considering the area of the selected glass is not major compared to other buildings with full glass façade.

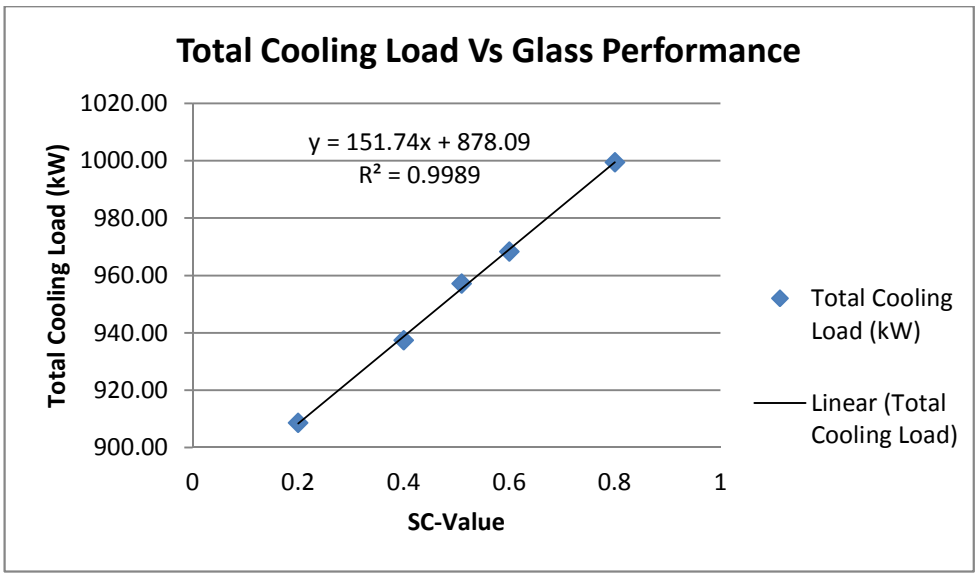


Figure 4.1: Graph of E_{cl} Vs. Glass Performance (SC-Value)

From the result obtained, it was found that with the E_{cl} increases linearly proportional with the increase SC-Value of the selected glass. From the plotted graph, the relationship between the E_{cl} and SC-Value can be expressed as with the following expression:

$$E_{cl} = 151.74 \times SC + 878.09 \quad (4.1)$$

This is expected as with a higher SC-Value of the glass, more heat gain is transferred into the air conditioned space through the glass and more cooling is required to overcome this heat. Although the value from the finding may not be applicable to other buildings, the finding itself proves that glass performance has a direct impact on the total cooling load requirement.

4.3.2 Total Cooling Energy (E_c) Consumption Result

E_c consumption from equipment depends very much on the COP of the selected equipment. By determining the COP value, the E_c consumption can be obtained. As the case study building adopts the use of VRV system which is a type of air-cooled DX, the norm benchmark COP is 3. Thus by dividing the total cooling load required obtained from the E-20 simulation with the selected COP value, the E_c consumption was obtained as follows:

Table 4.12: Summary E_c with Different Glass SC-Value

Glass SC-Value	0.2	0.4	0.51	0.6	0.8
E_c (kW)	302.90	312.50	319.07	322.80	333.17

With different equipment selection, the COP may varies and usually more than 3. Using different system as such water cooled system would give even higher COP value and this will reduce significantly the E_c consumption required.

4.4 RELATIONSHIP BETWEEN ENVELOPE THERMAL TRANSFER VALUE (ETTV) AND TOTAL COOLING ENERGY (E_c) CONSUMPTION

From the obtained calculated ETTV result for each variation of SC-Value for the 13.53 mm Clear Sunergy Glass and each of its corresponding E_c consumption, a graph can be plotted with ETTV against E_c consumption. These values are shown respectively in Table 4.3 and Table 4.7.

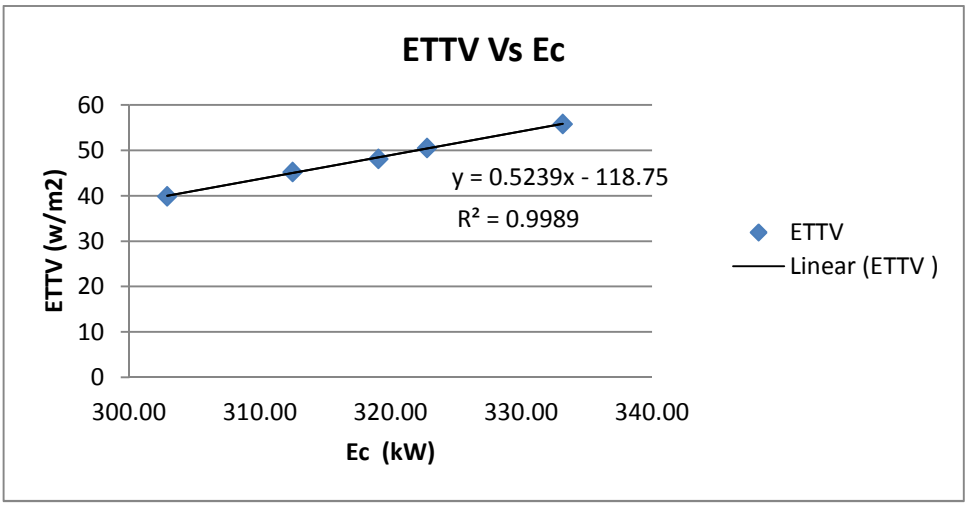


Figure 4.2: Graph of ETTV Vs. E_c

From the result and the plotted graph, it was found that ETTV is linear against both cooling load and also the E_c consumption with the following expression.

$$ETTV = 0.5239 \times E_c - 118.75 \quad (4.2)$$

Based on the studied mixed development building, it was found that with every ETTV value increase, the E_c consumption increases by up to 1.95 kW based on a minimum COP of 3. Thus it can also be expressed that the E_c consumption for the studied mixed development building can be reduced by up to 0.5% with every ETTV value drop with the current building configuration. Although the value in this study is only applicable to our chosen mixed development building, it nevertheless gives a valid general conclusion that a low ETTV value reduces the heat gain to a building thus reduces the total required cooling load and therefore gives a lower E_c consumption.

This finding is significant to prove that huge saving in energy can be obtained with the control of ETTV value as it is one of the determining factors in obtaining the total cooling load required for a building operation in general and more so in large scale development. This finding coincide the methodology employing OTTV to obtain energy estimation proposed by Chou and Chang (1993). In addition, with the right selection of air conditioning with high efficiency can also significantly reduce the required energy use to produce the same amount of cooling.