CHAPTER IV

RESULTS

These results had 2 systems: first system was results of OTTV, RTTV, energy saving, and payback period from house model and the second was results from computer simulation.

House Model

The first part, the house model in this thesis had the specification as follows: using area was 171.24 m^2, 2 floors, 3 bedrooms, 3 bathrooms, 1 living room, 1 parlor, 1 kitchen and 1 car park. The direction of parlor was in the north, living room in the southeast, bathrooms in the west, kitchen in the west, car park in the north, bedroom 1 in the north, bedroom 2 in the east and bedroom 3 in the southeast. The roof had pitched roofs 30°. Ratio of areas between glasses and walls were more 0.17. Windows and doors used clear glass. The roof tiles were used asbestos cement tiles. This house was used brick masonry walls with cement coated and thickness 10 cm. The color of roof was medium brown paint and wall was white semi-gloss.

The values of OTTV and RTTV of house model from processing of calculation were show on the Table 19 and Table 20.

Table 19 Results of Over Thermal Transfer Value of the House Model before Install Insulation and Change the Glass Wall.

Room*	Direction	A_w (m^2)	A_g (m^2)	A (m^2)	U_w ($W/m^2\,°C$)	U_g ($W/m^2\,°C$)	SC_1	SC_2	SF	OTTV (W/m^2)
Living and Parlor Room	North	7.54	4.95	12.48	3.47	5.83	0.92	1	112.0	89.08
	East	9.69	7.99	17.68	3.47	5.83	0.92	1	179.2	123.69
	South	6.24	6.24	12.48	3.47	5.83	0.92	1	177.6	131.67
Bed Room No 1	North	9.66	3.50	13.16	3.47	5.83	0.92	1	112.0	73.50
	East	8.86	1.75	10.64	3.47	5.83	0.92	1	179.2	71.41
	West	8.86	1.75	10.64	3.47	5.29	0.92	1	164.8	68.34
Bed Room No. 2	North	7.49	1.75	9.24	3.47	5.83	0.92	1	112.0	64.34
	East	7.49	1.75	9.24	3.47	5.83	0.92	1	179.2	76.05
Bed Room No. 3	East	7.49	1.75	9.24	3.47	5.83	0.92	1	179.2	76.05
	South	12.25	1.75	14.00	3.47	5.83	0.92	1	177.6	64.18

Table 20 Results of Roof Thermal Transfer Value and Heat Flow Rate of the House Model before and after Install Insulation.

Room*	Layout of Ceiling	Ac (m^2)	TD_t (°C)	Ur_0 ($W/m^2\,°C$)	RTTV(a) (W/m^2)
Living and Parlor Room	-	-	-	-	-
Bed Room No. 1	Parallel with floor	20.00	32.00	1.41	45.17
Bed Room No. 2	Parallel with floor	12.25	32.00	1.41	45.17
Bed Room No. 3	Parallel with floor	17.50	32.00	1.41	45.17

* The position of rooms shown on figure 6 and the direction of house's front were set upped in the north.

The results of this process were highest than standard because the current OTTV limits were for building, OTTV $\leq$ 45 W/m^2 and for roof, RTTV $\leq$ 25 W/m^2.

So that we can changed the result of OTTV and RTTV to based on standard by install insulation for wall and change glass of window as following:

Living and parlor room install fiber glass insulation that has thickness 2 inch, and change clear glass to laminated glass in north direction and others change to heat stop glass. Likewise, bed room number 1, 2, and 3 install fiber glass 2 inch thickness for wall

and roof change clear glass to laminated glass. The results in these processes were showed in Table 21.

After modify the materials, we can see that the OTTV and RTTV have the value lower than standard accordingly the value of energy saving in each room are as follows:

Table 21 Results of Over Thermal Transfer Value of the House Model after Install Insulation and Change the Glass Wall

Room*	Direction	A_w (m^2)	A_g (m^2)	A (m^2)	U_{w0} ($W/m^2\,°C$)	U_{g0} ($W/m^2\,°C$)	SC_1	SC_2	SF	OTTV (W/m^2)
Living and Parlor Room	North	7.54	4.94	12.48	0.58	2.42	0.35	1	112.0	29.28
	East	9.69	7.99	17.68	0.58	1.15	0.19	1	179.2	24.38
	South	6.24	6.24	12.48	0.58	1.15	0.19	1	177.6	26.09
Bed Room No. 1	North	9.66	3.5	13.16	0.58	2.42	0.35	1	112.0	21.93
	East	8.86	1.75	10.61	0.58	2.42	0.35	1	179.2	20.11
	West	8.86	1.75	10.61	0.58	2.42	0.35	1	164.8	19.27
Bed Room No. 2	North	7.49	1.75	9.24	0.58	2.42	0.35	1	112.0	17.61
	East	7.49	1.75	9.24	0.58	2.42	0.35	1	179.2	22.06
Bed Room No. 3	East	7.49	1.75	9.24	0.58	2.42	0.35	1	179.2	22.06
	South	12.25	1.75	14	0.58	2.42	0.35	1	177.6	16.84

Table 22 Results of Roof Thermal Transfer Value and Heat Flow Rate of the House Model after Install Insulation.

Room*	Layout of Ceiling	Ac (m^2)	TD_r (°C)	Roof Insulation	Ur1 ($W/m^2\,°C$)	RTTV(b) (W/m^2)
Living and Parlor Room	-	-	-	-	-	-
Bed Room No.1	Parallel with floor	20.00	32.00	Glass Fiber 2 inch.	0.47	15.18
Bed Room No. 2	Parallel with floor	12.25	32.00	Glass Fiber 2 inch.	0.47	15.18
Bed Room No. 3	Parallel with floor	17.50	32.00	Glass Fiber 2 inch.	0.47	15.18

* The position of rooms shown on figure 6 and the direction of house's front were set upped in the north.

From Figure 13 show the results of OTTV before and after modify materials from house model in part of living and parlor rooms on the Table 19 and 21 by set the front of

this room in the north direction. The results shown south wall has high OTTV because in this direction absorbed heat from solar radiation all-time.

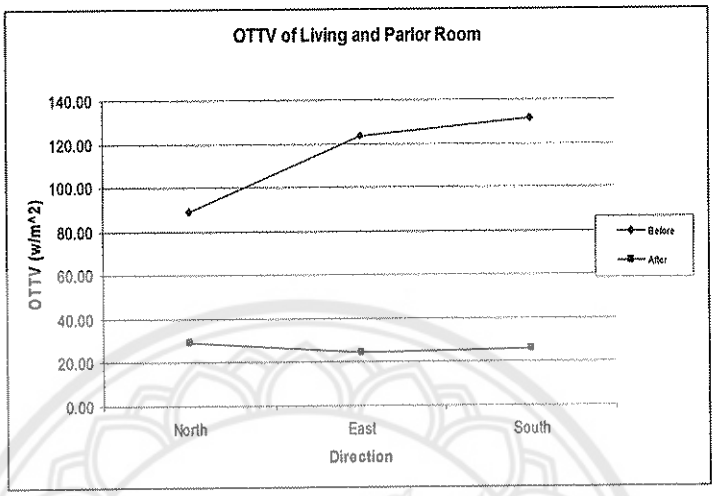

Figure 12 Results of OTTV before and after modify materials from living and parlor rooms.

From Figure 14 show the results of OTTV before and after modify materials from house model in part of bed room No.1 by set the front of this room in the north direction. And the directions of this room that absorbed radiation are north, east, and west. The data of graph are set from Table 19 and 21. OTTV of each wall in this room has a little bit difference values because this room that not absorbed direct solar radiation.

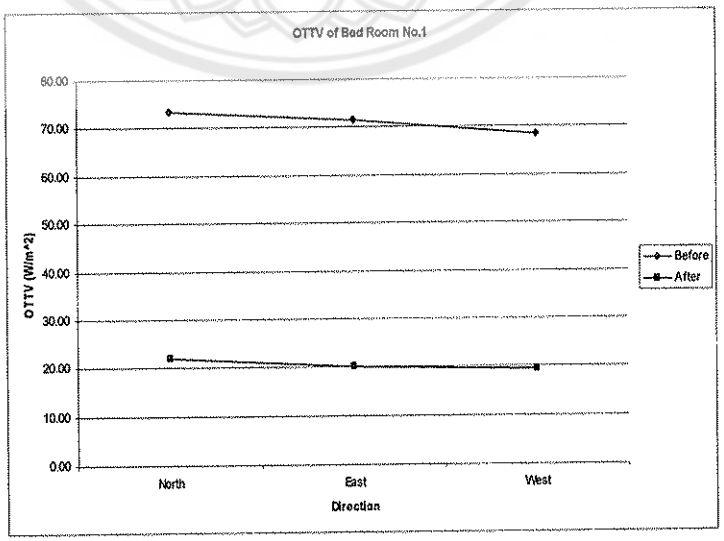

Figure 13 Results of OTTV before and after modify materials from bed room No.1.

From Figure 15 show the results of OTTV before and after modify materials from house model in part of bed room No.2 by set the front of the house model in the north direction. In this case, the bed room No.2 has the wall that absorbed radiation 2 sides from 4 sides. In the same reason with Bad Room No.1; OTTV values is around 65-75 W/m^2. It is lower than OTTV of living room that OTTV value has around 90-130 W/m^2.

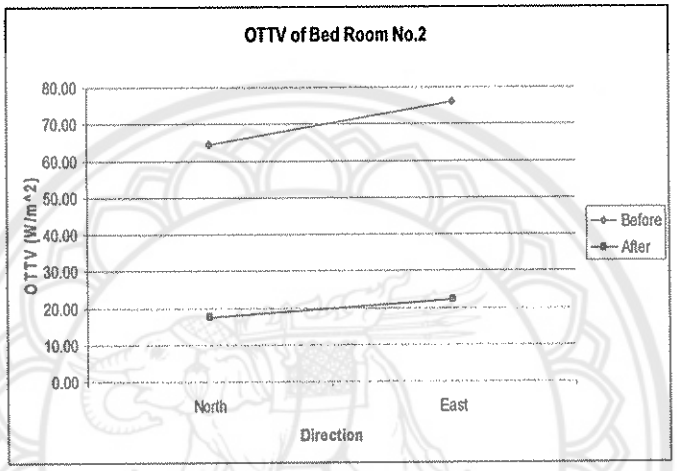

Figure 14 Results of OTTV before and after modify materials from bed room No.2.

From Figure 16 show the results of OTTV before and after modify materials from house model in part of bed room No.3 by set the front of the house model in the north direction. In this case, the bed room No.3 has the wall that absorbed in the east and south direction.

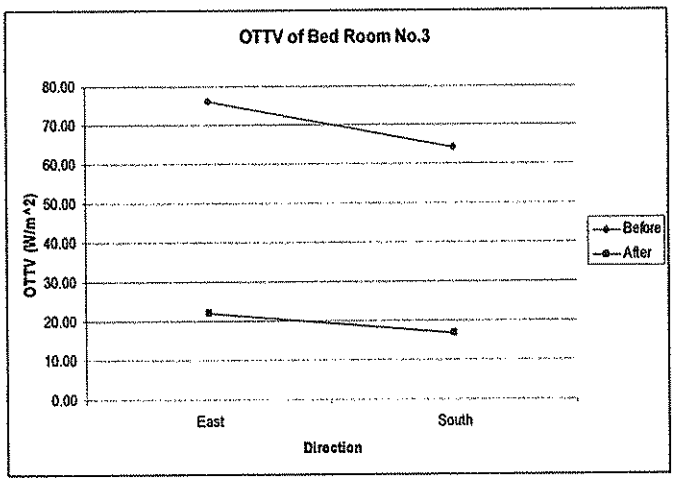

Figure 15 Results of OTTV before and after modify materials from bed room No.3.

Computer Program

Therefore, the second of results from computer program, mentioned in chapter III, were used to calculate the performance of this system for user. The development computer program to the mathematical models for energy saving consumption

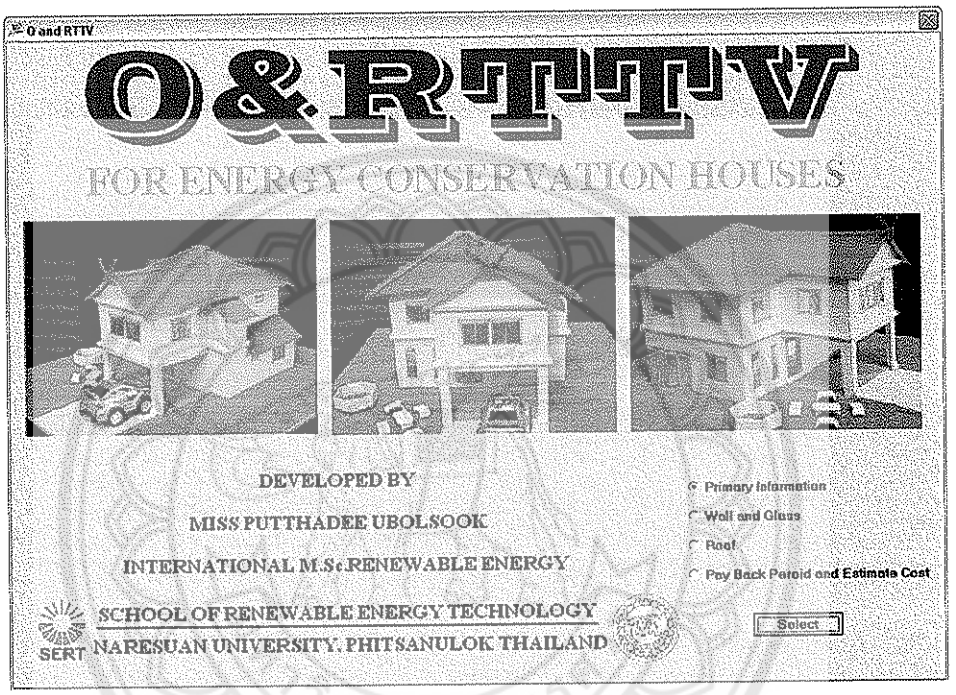

Figure 16 Display screen of the first page from computer program.

Input Parameters

In this study, there are four main groups of input parameters: primary information, opaque and transparent wall, opaque roof and pay back period.

The first group is primary information input parameters as follows (Figure 17)

- Number of occupants in your house
- Size of room or house (length, wide, high), (m)
- The temperature outdoor and temperature indoor.
- Time in hours to use air per day
- Days for use air in one year

The parameters for example of the primary information have 4 numbers of occupants, size of room are 6.8 meter of long, 4.8 meter of wide and 2.6 meter of high. Besides, temperature outdoor is 35 C° and indoor is 25 C°, air condition is run in 10 hours in one day and 365 days in one year.

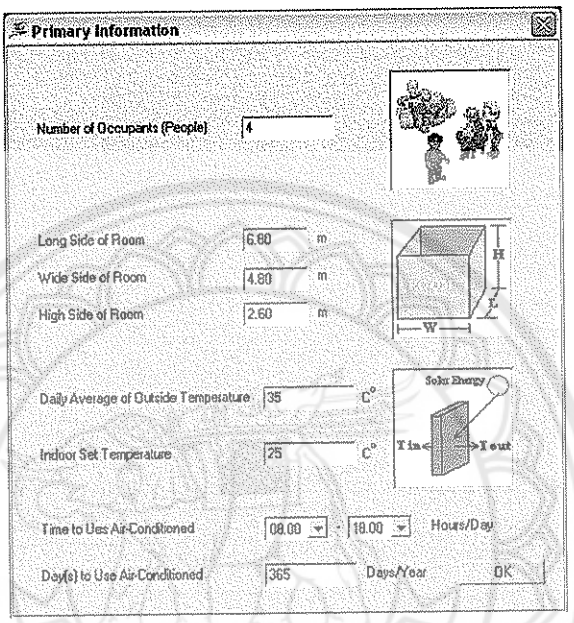

Figure 17 Show the primary information input parameters page of O&RTTV

The second group is opaque and transparent wall that are data for calculation OTTV. There are consists of ten parameters as follows (Figure 18)

- Side of walls that are absorbed radiation.
- Estimate position of room, choose one from four positions.
- Direction of wall and/or glass, which allow user to select one from eight codes (North, Northeast, East, Southeast, South, Southwest, West, Northwest)
- Section code of wall. There are three choices for this item i.e. opaque wall only, transparent wall only and opaque with transparent wall.
- Types of wall and/or glass materials such as brick wall, brick wall with cement coating, concrete wall, Hardwoods wall, clear glass and others
- Area of wall and/or glass in term of square meter (m^2)
- Shading for windows, which user to select one from two types.

(Overhang or Fin)

- Color for wall, there are 50 choices for this items such as black glass, black concrete, stafford blue brick, bituminous felt, blue grey slate and other.

- Slope of wall in degree from 70° to 90°.

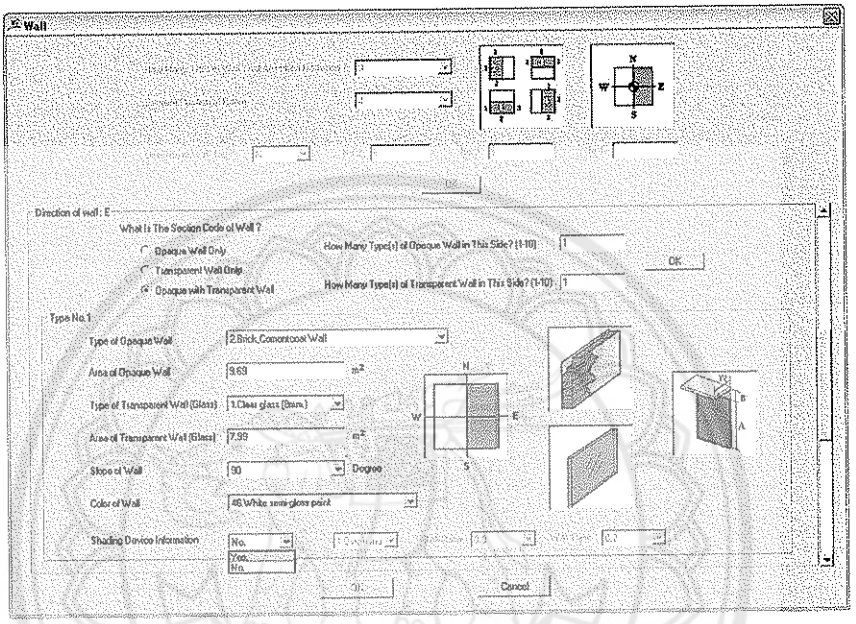

Figure 18 Data input screen for OTTV calculation.

The example of this page is follows as: 3 sides wall that absorbed radiation, the position of room is No. 3, and wall direction of this room are north, south, and east but this page was considerate in east direction. For this wall side are 2 types of walls: opaque wall is brick with cement coating and transparent wall is clear glass. Area of opaque wall are 9.69 m^2, transparent wall are 7.99 m^2. Therefore, slope of wall is 90 degrees and color is whit semi gloss and no shading for window glass.

The third group is input data for RTTV calculation. There are consists of ten parameters as follows (Figure 19).

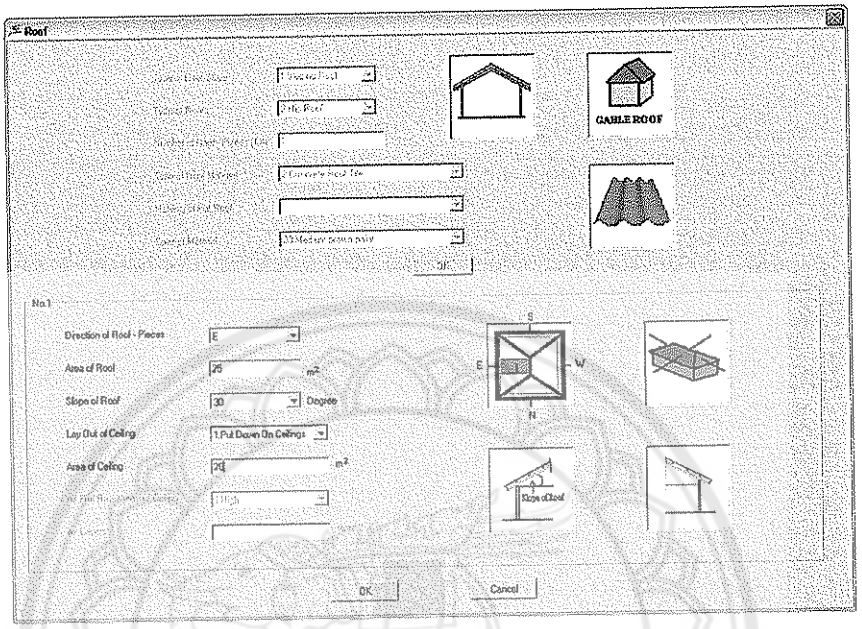

Figure 19 Data input screen for RTTV calculation.

- Types of steep roof, user can select one from two types; Sloping roof and Flat roof.

- Types of roof are the character of roof such as gable roof, hip roof, shed roof and salt box roof.

- Numbers of roof-pieces are put on the room.

- Direction of roof, which allow user to select one from eight codes (North, Northeast, East, Southeast, South, Southwest, West, Northwest)

- Area of roof in term of square meter (m^2)

- Slope of roof in degree from 0° to 60°

- Types of materials roof are many types such as asbestos cement roof tile, concrete roof tile, corrugated roof tile and other.

- Color of materials, there are many choices for this items such as black glass, black concrete, Stafford blue brick, bituminous felt, blue grey slate and other.

- Lay out of ceiling, user can select sample of layout of ceiling such as cathedral ceiling, parallel with floor or no ceiling
- Area of ceiling in term of square meter (m^2)
- Absorbtivity of material is high or low
- Air layers of roof between materials roof and ceiling in case of cathedral ceiling.

The example for RTTV calculation is parameters as follows: sloping roof types is hip roof, type of materials of roof is asbestos cement tile, color is medium brown paint, slope of roof is 30 degrees, area of ceiling is equal 20 m^2, and parallel with floor.

And the last group is Economical Data input: consists of many parameters as follows (Figure 20)

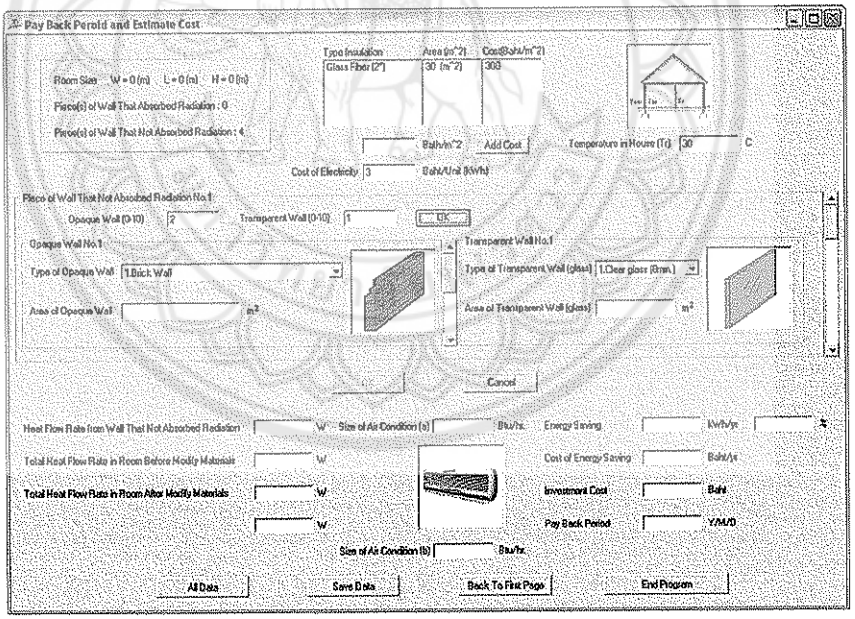

Figure 20 Data input screen for Economic Data input, heat, and energy saving.

- Pieces of wall that are absorbed radiation.
- Pieces of wall that are not absorbed radiation
- Temperature in house, (C°)
- How many types of internal wall?

- Types of internal material wall such as clear glass, brick wall, cement block wall and other
- Area of internal wall in term of square meter, (m^2)
- Cost of Insulation, (Bath/ m^2) and cost of electricity, (Baht/Unit)

The parameters of this page have follows: insulator cost of fiber glass is equal 250 baht/m^2, heat stop glass is equal 1200 baht/m^2, cost of electricity is equal 2.7 baht/unit, temperature in house is 30 C, and areas of wall that not absorbed radiation have brick with cement coating is equal 11.79 m^2, hard wood is equal 1.52 m^2 and clear glass is equal 4.37 m^2.

The Performance Calculation

The computer model calculate the performance of all systems show the following conditions:

For the screen of OTTV (Figure 21) results were used the equation 2.3 of overall thermal transfer value for program computer. And find the total of overall thermal transfer value from equation 2.4. For example of calculation was showed in appendix A.

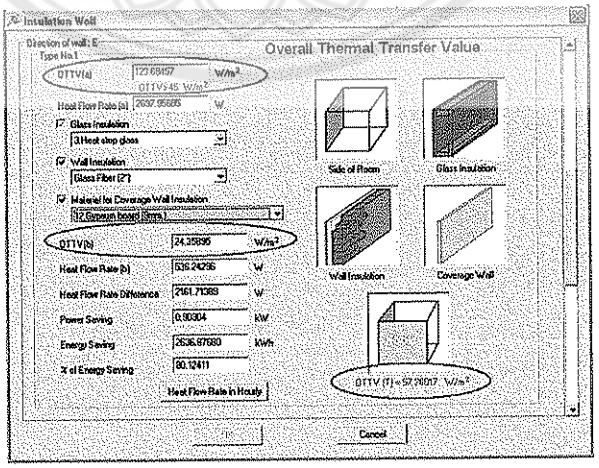

Figure 21 Display screen of OTTV result.

This calculation example is heat from building materials. In the calculation follows these showing in appendix D. And the results from the computer program was shown in Figure 22

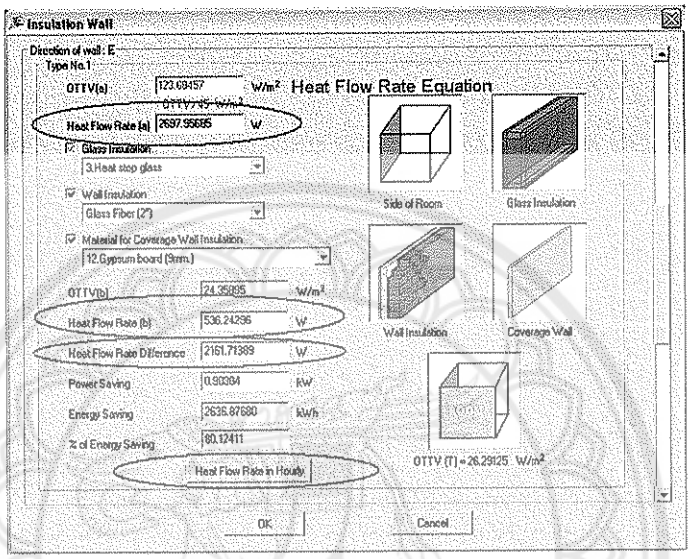

Figure 22 Display screen of heat result

After finding the reducing heat load you can calculate power saving follow from appendix E by equation as follows (Figure 23):

Power Saving = Heat Difference X 1/ average EER of air condition

when EER of air condition = 8.17 Btu/hr-W

When you find power saving, you can find energy saving by:

Energy Saving = Power Saving X Time X Day/yr. X Efficiency

And the calculation of percentage of energy saving is determined from equation 2.32.

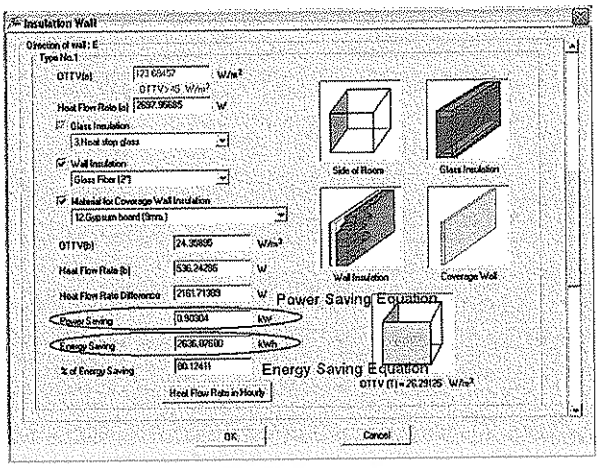

Figure 23 Display screen of power and energy saving result.

RTTV equation for roofs was similar to wall, but external shading was not considerate for roofs. The terms and coefficients (TD_r and SF) may very different OTTV standards. For the equation of RTTV was eq.2.5 from chapter II. And example of calculation was show in appendix B. The display screen of RTTV was shown in figure 24.

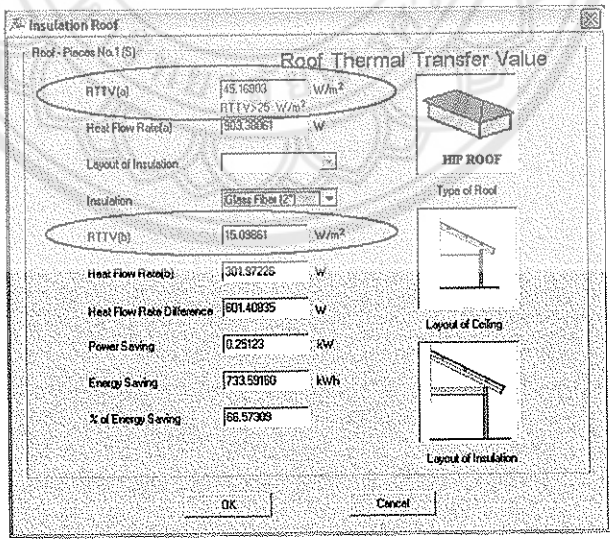

Figure 24 Display screen of RTTV results.

Heat for conditioned building (Q_r) from roof (W) use equation similar to heat flow rate from wall (OTTV). For example of these pages was showing the steps from appendix D. The display screen results of heat were shown in Figure 25.

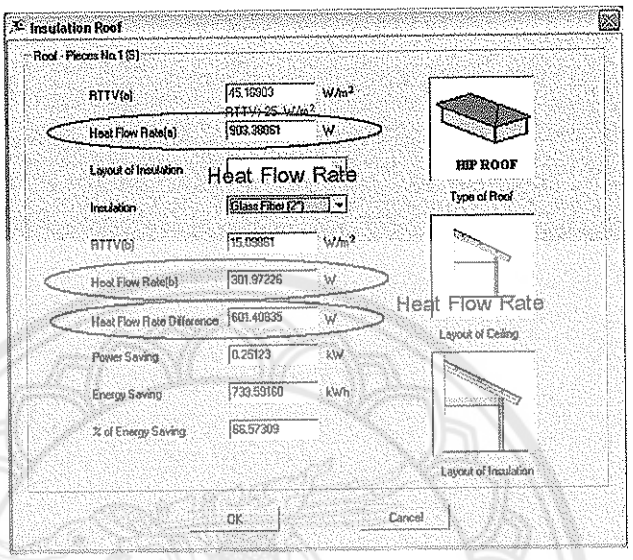

Figure 25 Display screen of heat result.

The heat difference, power saving, energy saving, and percentage of energy saving are similar to wall. And the values were shown on Figure 26.

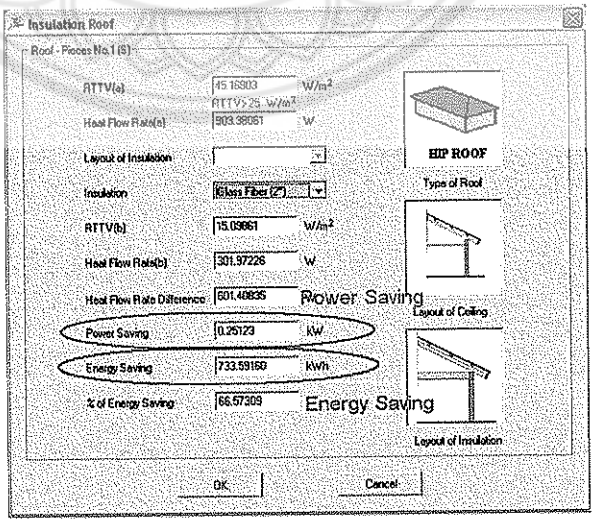

Figure 26 Display screen of power and energy saving of RTTV result.

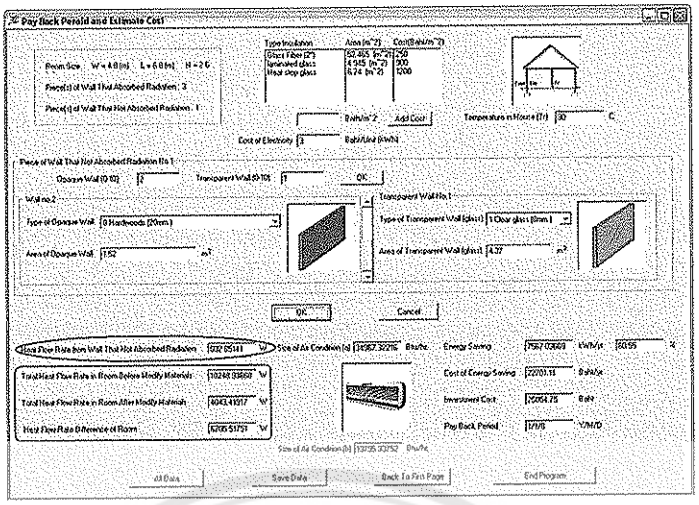

Figure 27 Display screen of heat data, size of air condition, energy saving and payback period result.

Heat for conditioned building from wall and roof use equation in part of heat conditioned building. For example of these pages was showing the steps from appendix D.

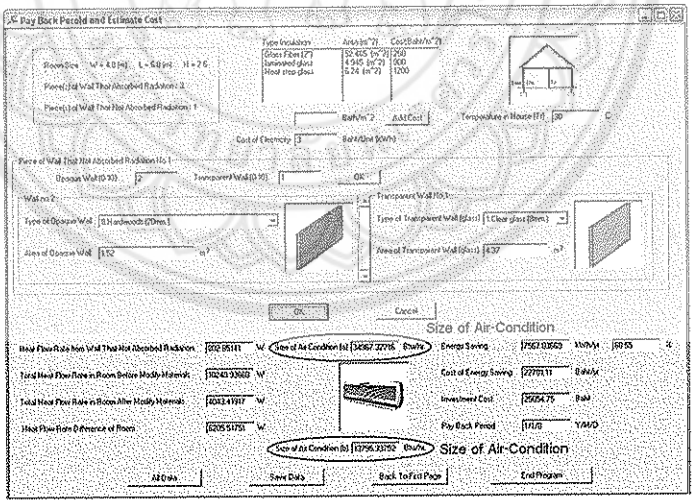

Figure 28 Display screen of size air condition

Size of air condition can calculate from the equation for finding the size of air condition is following:

$$Size\ of\ \ Air-Condition = 3.4118 \cdot Q_m$$

where Q_m = Total heat flow rate (W) equation 2.21

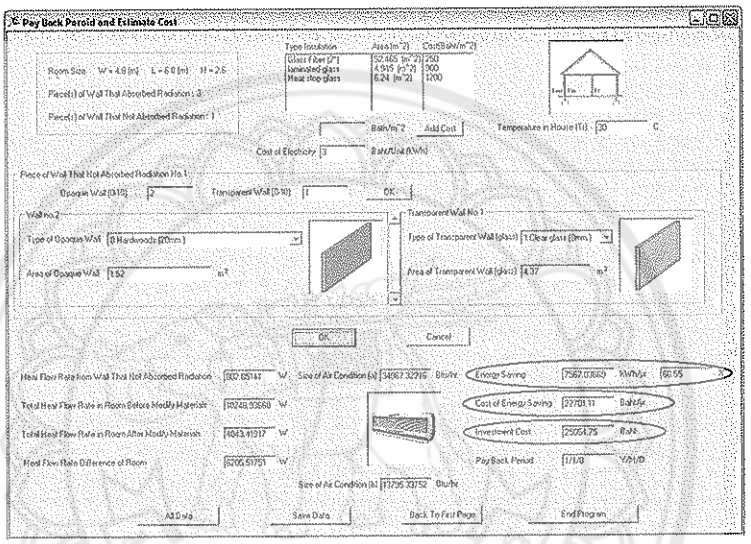

Figure 29 Display screen of energy saving, cost of energy saving and payback period result

This page was showed part of energy saving in one year (kWh/yr) and percentage, cost of energy saving, investment cost and payback period. In appendix E was show the steps of calculation for this play screen.

Results Displaying from Computer Program

This section is displaying figure and description of the result from the steps of calculation in process of OTTV and RTTV. After completing the input of the required parameters, the program will be calculated the data and show in next page (Figure 30, 31). The displayed system descriptions are as follows:

- OTTV/RTTV: shows the OTTV/RTTV system in each side.
- Heat Load: shows the heat that through from material building.
- Type of insulation: shows the insulation that can reduce the load.
- OTTV/RTTV: shows the OTTV/RTTV system in each side after install insulation.
- Heat Load: shows the heat that through from material building after install insulation.
- Power Saving: shows the electric energy saved by insulation.
- Energy Saving: shows the data of energy saving from this side.
- % of Energy Saving: shows the percents of energy saving.

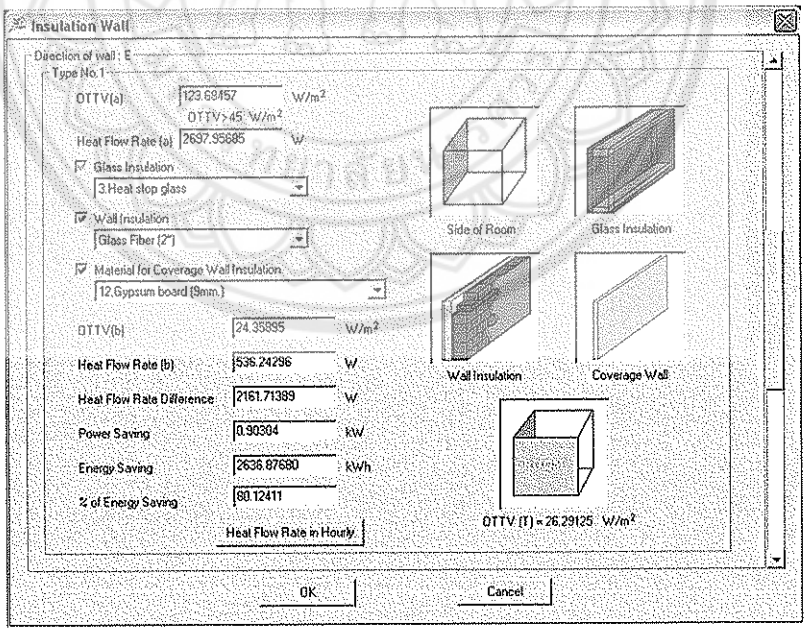

Figure 30 Displaying screen of the result from the steps of calculation in process of OTTV

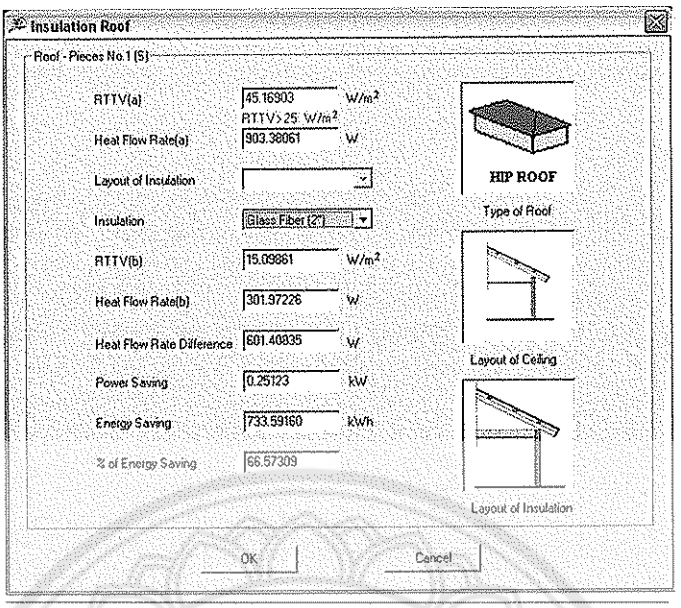

Figure 31 Displaying screen of the result from the steps of calculation in process of RTTV

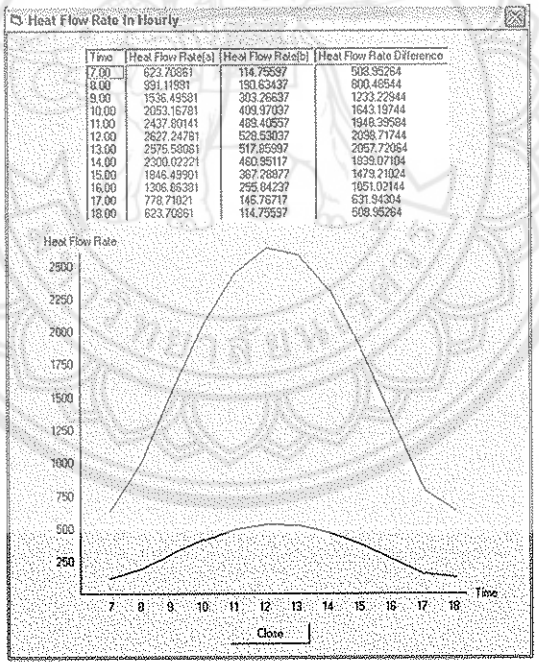

Figure 32 Displaying screen of the result from the steps of calculation in process of heat flow rate in hourly.

The last section of the results after completing the input of the required parameters, the program will be calculated the data and show on this page (Figure 33).

Therefore, the data will show as follow: the size of air condition, cost of installation investment cost and pay back period.

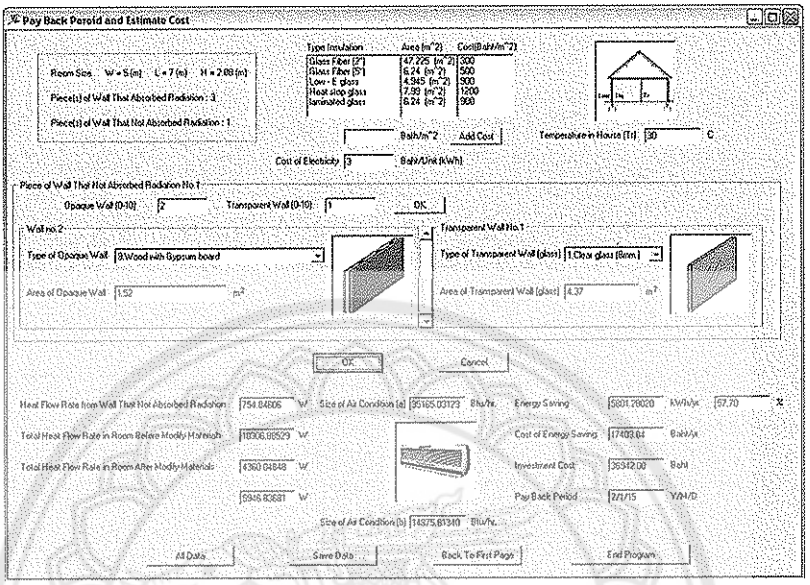

Figure 33 Show the last section of the results after completing the input of the required parameters

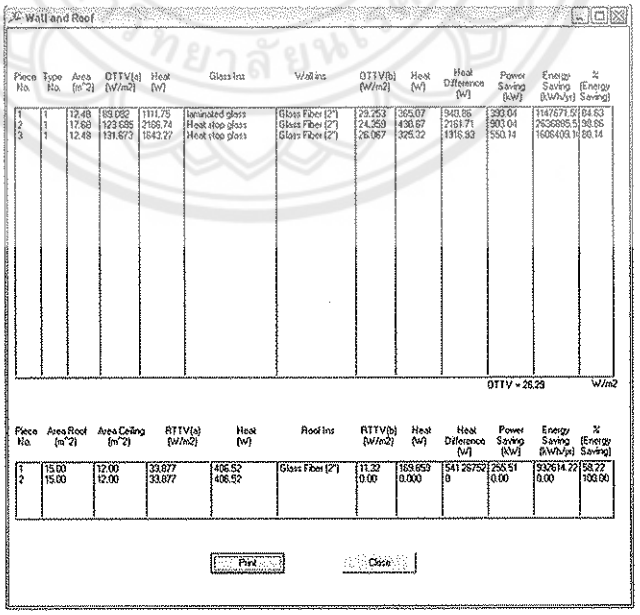

Figure 34 Display screens of all data from computer program

Results of OTTV Calculation from Computer Program

For this example was set value of room model from the living and parlor room of the house model from figure 35. Accordingly, the areas of fist direction were 12.48 m^2, second direction was 17.68 m^2 and the last was 12.48 m^2 and set the front of this room in 8 directions. Therefore, after modify the OTTV by change only clear glass to heat stop glass, the value of calculation were show in Table 23.

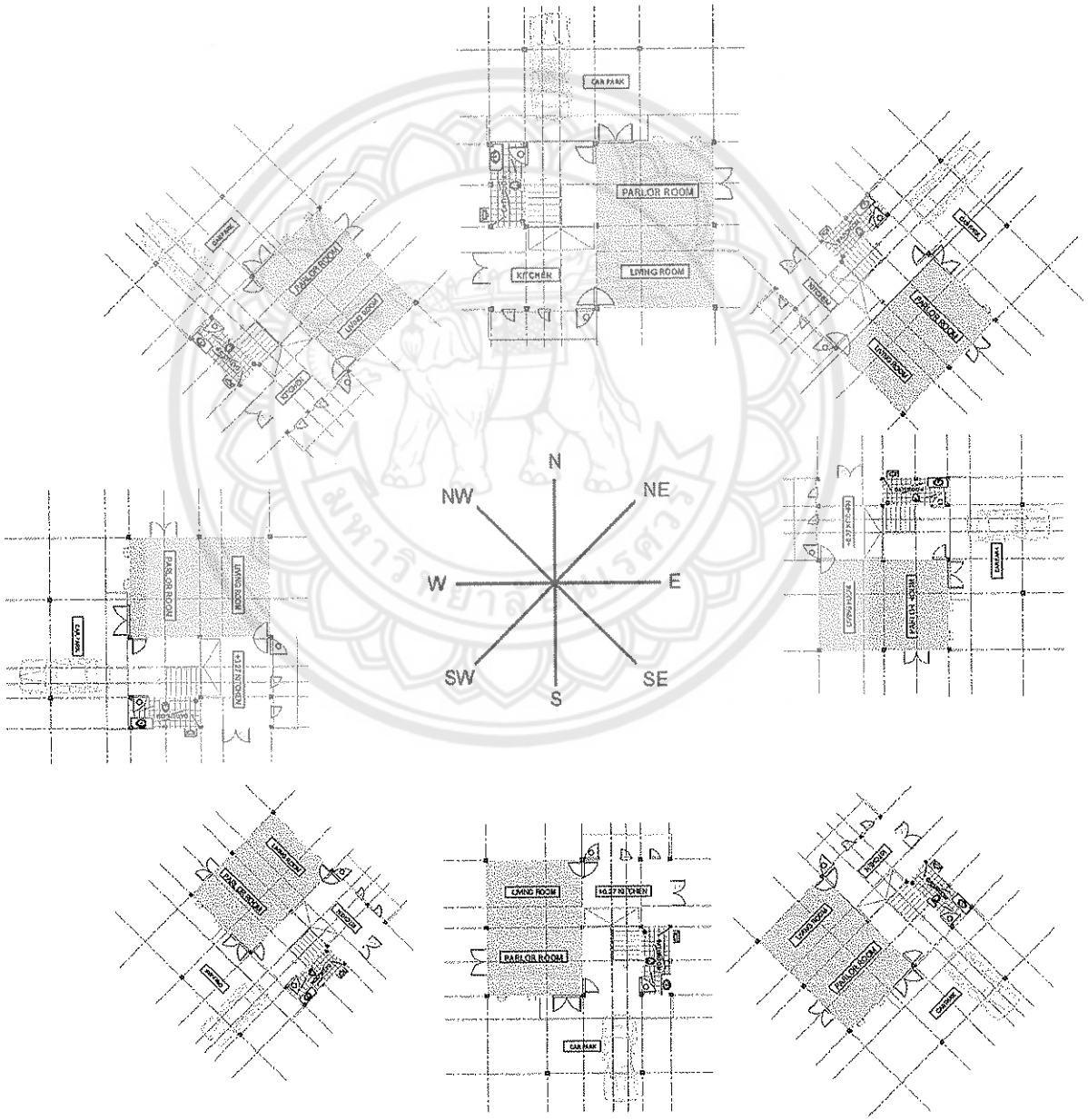

Figure 35 Position of house's front setting

Table 23 Result of OTTV from Sample House That are Set Up in 8 Directions.

Set Direction*	Direction**	Area m^2	OTTV(a)*** W/m^2	Heat(a) W	OTTV(b)*** W/m^2	Heat(b) W	Δ OTTV W/m^2	Δ Heat W	% Saving
North	N	12.48	89.08	1425.12	38.16	540.95	50.92	884.17	62.04
	E	17.68	123.69	2697.96	43.44	873.51	80.25	1824.45	67.62
	S	12.48	131.67	1641.98	43.47	542.24	88.20	1099.74	66.98
	Overall OTTV	42.64	115.90	5765.06	41.90	1956.70	-	-	-
Northeast	NE	12.48	99.00	1581.40	40.21	573.22	58.79	1008.18	63.75
	SE	17.68	127.01	2496.83	44.12	831.97	82.89	1664.86	66.68
	SW	12.48	133.15	1950.74	43.77	606.00	89.37	1344.74	68.93
	Overall OTTV	42.64	120.61	6028.97	42.87	2011.19	-	-	-
East	E	12.48	113.58	1735.11	43.22	604.97	70.36	1130.14	65.13
	S	17.68	123.02	2173.33	43.30	765.16	79.72	1408.17	64.79
	W	12.48	125.79	2128.94	42.25	642.81	83.53	1486.13	69.81
	Overall OTTV	42.64	121.07	6037.38	42.97	2012.94	-	-	-
Southeast	SE	12.48	116.50	1610.31	43.82	579.19	72.67	1031.12	64.03
	SW	17.68	124.35	2568.68	43.57	846.81	80.78	1721.87	67.03
	NW	12.48	101.50	1662.18	37.24	546.41	64.26	1115.77	67.13
	Overall OTTV	42.64	115.36	5841.17	41.79	1972.41	-	-	-
South	S	12.48	113.00	1409.15	43.10	537.65	69.90	871.50	61.85
	W	17.68	117.70	2796.85	42.20	893.93	75.50	1902.92	68.04
	N	12.48	101.50	1662.18	37.24	546.41	64.26	1115.77	67.13
	Overall OTTV	42.64	111.58	5868.18	41.01	1977.99	-	-	-
Southwest	SW	12.48	114.16	1652.92	43.34	587.99	70.82	1064.93	64.43
	NW	17.68	95.75	2199.19	37.67	770.50	58.08	1428.69	64.96
	NE	12.48	114.01	1857.98	39.82	586.85	74.19	1271.13	68.41
	Overall OTTV	42.64	106.48	5710.09	39.96	1945.34	-	-	-
West	W	12.48	108.33	1793.82	42.13	617.09	66.20	1176.73	65.60
	N	17.68	95.75	2199.19	37.67	770.50	58.08	1428.69	64.96
	E	12.48	132.41	2051.71	43.62	626.86	88.79	1424.85	69.45
	Overall OTTV	42.64	110.16	6044.72	40.72	2014.45	-	-	-
Northwest	NW	12.48	89.08	1425.12	38.16	540.95	50.92	884.17	62.04
	NE	17.68	107.05	2449.91	40.00	822.28	67.05	1627.63	66.44
	SE	12.48	136.09	1894.63	44.38	594.42	91.71	1300.21	68.63
	Overall OTTV	42.64	110.29	5769.66	40.74	1957.65	-	-	-

* Set Direction is a position of house's front setting refer to figure 35

** Direction is the wall direction of living and parlor room that absorbed solar radiation.

*** (a) Before improvement, (b) After improvement

Effect of Direction for OTTV

From figure 36 show the results of OTTV from house model that run by computer program in 8 directions and show the value of OTTV before and after modify insulator. That can be concluded that in the east found highest heat because of the total heat gain in this from the east, south and west are higher than other directions and in this directions absorbed heat from solar radiation all-time. Next, in the northeast and the north found the heat reducing respectively.

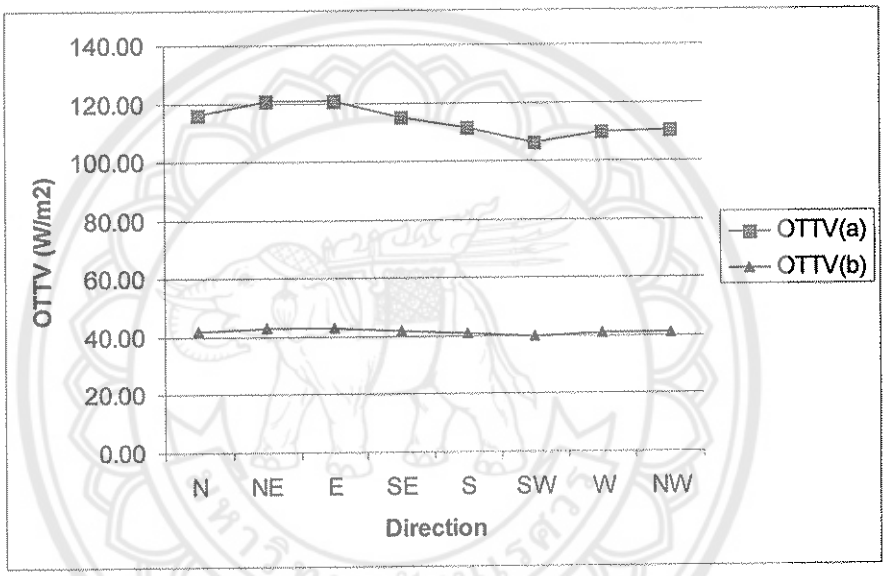

Figure 36 Results of OTTV before and after modify insulator in 8 Directions

(a) Before improvement, (b) After improvement

Effect of Shading for OTTV

Shading can reduce heat gain from solar radiation through the room. The data in Table 24 had shown the effect of shading for OTTV results in case of the house's front direction in the north. Overhang has areas m2 (w=1.2, l= 1.2). It was installed over the window 40 cm on the wall.

Table 24 Results of Overall OTTV in Case of No Shading and Shading from Overhang.

Shading	Direction of Living Room	Area m^2	OTTV(a) W/m^2	Heat(a) W	OTTV(b) W/m^2	Heat(b) W	Δ OTTV W/m^2	Δ Heat W	% Saving
No	N	12.48	89.082	1425.120	38.159	540.950	50.923	884.170	62.042
Overhang	N	12.48	80.231	1246.750	36.386	617.600	43.845	629.150	50.463
No	E	17.68	123.685	2697.960	43.435	873.510	80.250	1824.450	67.623
Overhang	E	17.68	90.827	1891.600	24.159	532.710	66.668	1358.890	71.838
No	S	12.48	131.673	1641.980	43.470	542.240	88.203	1099.740	66.976
Overhang	S	12.48	87.230	1088.040	25.885	322.780	61.345	765.260	70.334

From the results found that, it was installed the overhang in south direction can reduce highest heat gain (Figure 37). Because the south direction was absorbed the direct solar radiation. When compare the south with the north direction that was not absorbed direct radiation then in this direction has lower OTTV values.

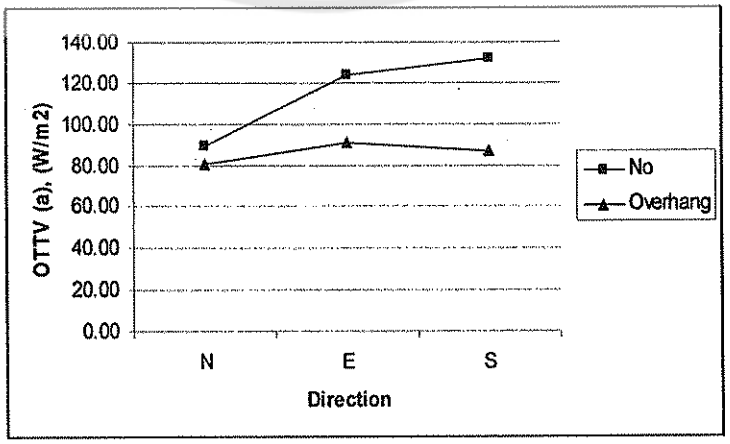

Figure 37 Results of OTTV in Case of No Shading and Shading from Overhang

Effect of Ratio between Transparent and Opaque Wall

Heat gain came through rooms via transparent wall was higher than opaque wall. So that OTTV value is the direction proportion with ratio between transparent wall and opaque wall, meanwhile the ratio are increase, OTTV are increase too.

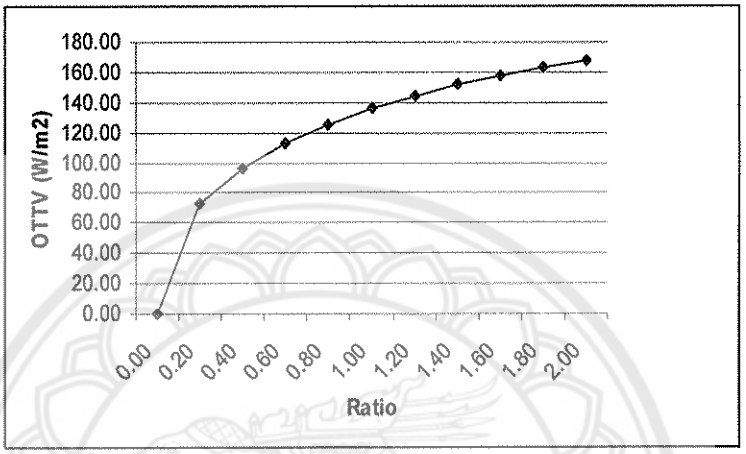

Figure 38 Results of OTTV with Ratio between Transparent Wall and Opaque Wall.