CHAPTER IV

RESULT AND DISCUSSION

The result and analysis chapter consist of two objects. The first object shows the LPG consumption of solar absorption cooling system at SERT compared the designed data. The second show the effected of diffuse fraction, H_d/H, to the LPG consumption:

A solar-powered air conditioning system has been installed at SERT in Naresuan University. The system employs the evacuated heat tube collector area of 81.78m^2 (aperture area). The designed cooling capacity is 10 tons of refrigeration. The weather data was recorded regularly by a personal computer based data acquisition system custom designed. The analysis was performed with time-step intervals of 15 minutes.

The average of the collected data were calculated using the equations litsted in Chapter III during measuring duration from September to January 2005-2006, and show in table 13

Table 13 The average of collected data from September to December

Item	Sep	Oct	Nov	Dec	Jan	Unit
Inclined irradiation	593.6459 (540)	591.9911 (507.3750)	632.0962 (505)	597.2741 (558.5)	619.9229 (617.3750)	W/m^2
Energy supply from collector	111.7896 (289.93)	142.4421 (269.5525)	132.8378 (270.18)	198.7269 (306.9046)	163.0385 (345.3095)	W/m^2
LPG consumption	5.5217	3.1900	7.2257	3.4325	0.0350	kg/day
LPG consumption	74.3738 (34.67903)	42.9675 (37.42525)	97.3263 (33.8155)	46.2339 (26.19823)	0.4714 (1.6196)	kWh/day
Flow rate via collector	0.79620	0.8765	0.8651	0.9588	0.9549	kg/s
Diffuse fraction (H_d/H)	0.7115	0.6265	0.5123	0.5812	0.5840	

Table 13 (Cont.)

Item	Sep	Oct	Nov	Dec	Jan	Unit
Clearness index (K_T)	0.4253	0.48545	0.5555	0.5162	0.5140	
Efficiency of collector (η_c)	0.2195 (0.4850)	0.2290 (0.4589)	0.2176 (0.4555)	0.3371 (0.4739)	0.2510 (0.5063)	
Water temp. inlet collector (T_1)	69.6398	67.3435	72.8388	66.9105	66.7225	°C
Water temp. outlet collector (T_2)	73.3555	70.4368	75.7647	70.9746	69.9843	°C
Air Temp. (RT_6)	29.9409	29.2122	29.1888	32.6264	26.8922	°C
Average room Temp. (RT)	27.6416	26.4661	26.5928	31.0158	25.3287	°C

The numeric value in brace is designed data.

This system runs unsteadily frequently. So there are just data in September to January 2005 -2006 can be used to analyze. However the results of analysis still are desirable to optimize the LPG consumption in winter. This season has clear sky weather and optimum radiation

1. The result LPG consumption and diffuse fraction in September

The average of the collected data were calculated using the equations litsted in Chapter III during measuring duration in September 2006, and show in table 14

Table 14 The averages of data collected in September 2006.

Item	Numerical value	Unit
Inclined irradiation (540)[1]	593.6459	W/m^2
Rate of mass flow via collector	0.7962	kg/s
Energy supply from collector (289.93)[1]	111.7896	W/m^2
LPG consumption (34.67903 kWh/day)[1]	5.5217	kg/day
	74.3738	kWh/day
Efficiency of collector (0.4850)[1]	0.2195	
Diffuse fraction	0.7115	

[1]Designed data

From collected data in September 2006 and Designed data in September, the numerical value inclined irradiation of collected data is higher but the energy supply from collector and the efficiency of collector are lower. Because of in operate the system has high value diffuse fraction (the skies cover cloud). That made low efficiency of collector and supplying energy collector even high a daily solar radiation. So the LPG consumption is high.

Below, show example difference result between designed data and collected data in September 2006. On 7 Sep 2006 has a daily clearness index 0.5414 (54.14%). From table 13, then diffuse fraction is 53.82% so the weather condition on 7 Sep 2006 is cloudy day.

Table 15 Energy output from solar collector field and LPG consumption on 7 Sep 2006

time	η_C*	E_c* (W/m^2)	E_{cd} (W/m^2)	LPG	E_{aux} (kWh)	$E_{aux\text{-}d}$ (kWh)
9:00:00 - 10:00:00	0.25	132.32	316.602	0.28	3.77	4.95
10:00:00 - 11:00:00	0.19	118.23	402.169	0.19	2.56	1.04
11:00:00 - 12:00:00	0.32	275.43	432.315	0.15	2.02	0
12:00:00 - 13:00:00	0.30	298.67	412.380	0.16	2.16	0
13:00:00 - 14:00:00	0.32	311.45	347.760	0.18	2.42	0
14:00:00 - 15:00:00	0.48	294.05	248.230	0.12	1.62	2.74
15:00:00 - 16:00:00	0.39	236.91	131.428	0.39	5.25	7.38
16:00:00 - 17:00:00	0.41	191.66	15.386	0.89	11.99	18.56
Total		1835.9196	1858.72	2.36	31.79	34.67

*Average from every 15 minute

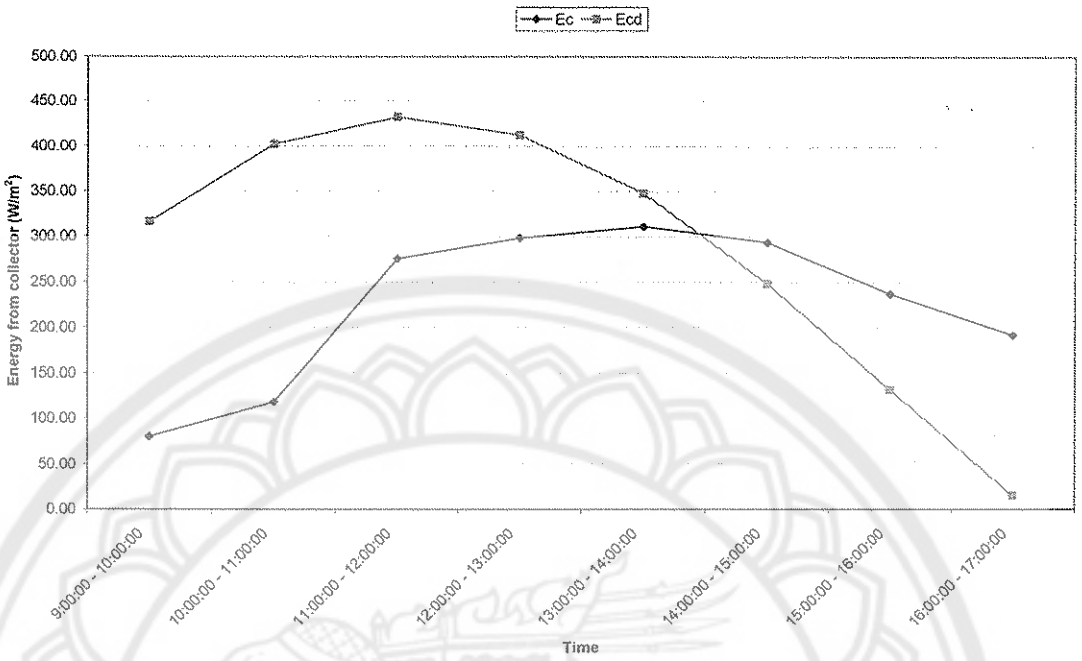

Figure 21 Energy supply by Solar collector between collected data on 7 Sep 2006 and designed data in September

From table 15 and figure 21, the power supply by solar collector of collected data is higher after 14.30pm. By the maximum collector efficiency (η_C) appearing in afternoon. At 10.00–11.00pm, the decreasing of energy from collector because of a rough of solar radiation from cloud.

On 7 Sep 2006, the mass flow rates are close value as means under fixed mass flow rate condition, the difference of water temperature between inlet and outlet of solar collector decrease as the water temperature at inlet of solar collector increase. That reduces the energy gain and makes the efficiency of collector drops. can see the this relationship in figure 22

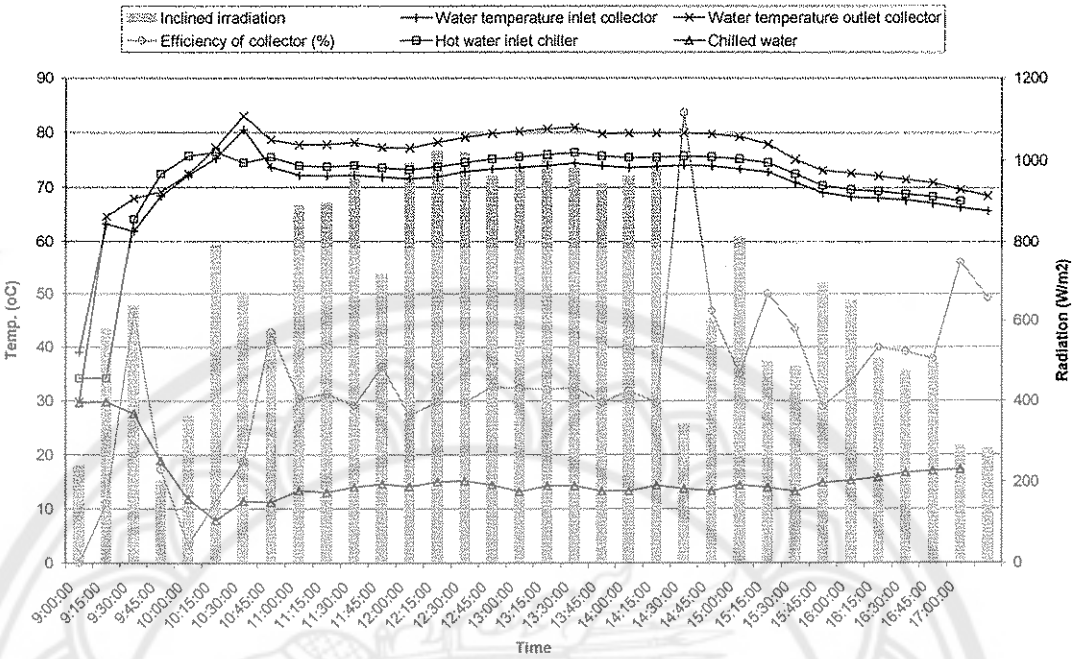

Figure 22 Energy supply by Solar collector between collected data on 7 Sep 2006 and designed data in September

The result of error in the temperature on start operation system may be from remaining water in tube. And may two reasons result in the both of starting temperature are too close:

1. The heat lost from both of hot and cold tank too much.

2. The system did not run continuously, no heat was stored in the tanks from previous days.

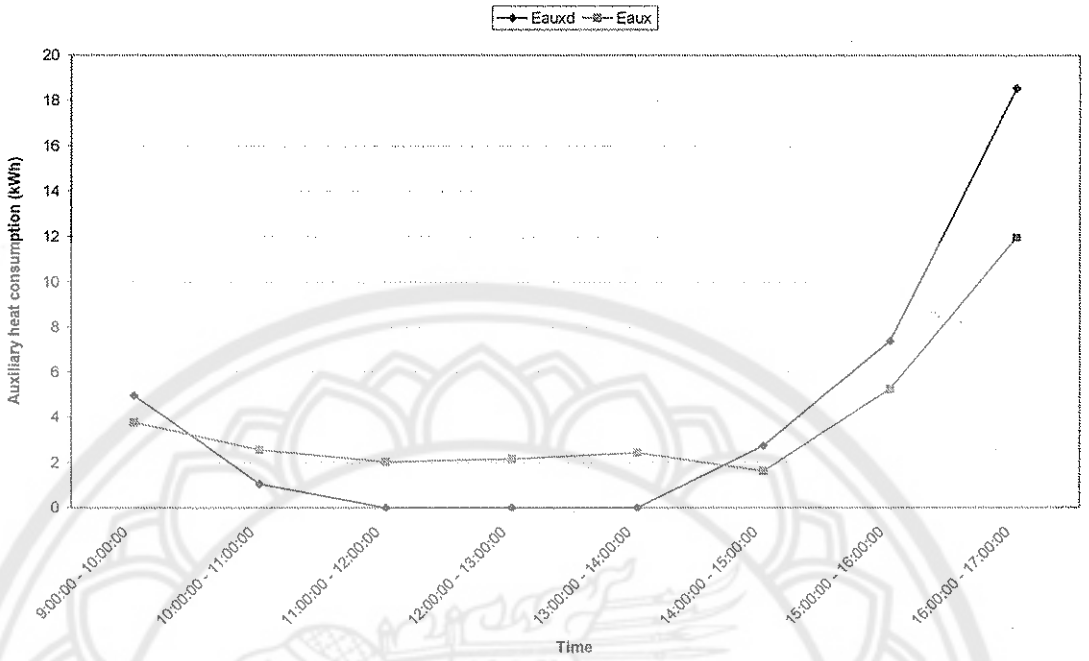

Figure 23 The auxiliary heat consumption between collected data on 7 Sep 2006 and designed data in September

From table 15 and figure 23, although the trend of auxiliary heat consumption (LPG) is nearly, that is the LPG consumption when start the system is higher and decrease in midday until after noon it increase again. But the LPG consumption on designs is higher rate consumption in afternoon because the energy supply from collector on 7 Sep 2006 is higher (figure 21).

The increasing of LPG consumption in afternoon is effect from the heating lag in structure building and furniture to emit the room and decreasing energy supply from collector. In collected data, the system has the used LPG all day because of high the average outside temperature room (32.92°C) that means high cooling load, so the energy consumption for transfer the appearing heat in the room is increase following.

2. The result LPG consumption and diffuse fraction in October

The average of the collected data were calculated using the equations listed in Chapter III during measuring duration in October 2005, and show in table 16

Table 16 The averages of data collected in October 2005.

Item	Numerical value	Unit
Inclined irradiation (507.3750)[1]	591.9911	W/m^2
Rate of mass flow via collector	0.8765	kg/s
Energy supply from collector (269.5525)[1]	142.4421	W/m^2
LPG consumption (37.42525 kWh/day)[1]	3.1914	kg/day
	42.9864	kWh/day
Efficiency of collector (0.4589)[1]	0.2290	
Diffuse fraction	0.6265	

[1]Designed data

From collected data and designed data in October, the result like in September. Although the inclined irradiation of collected data is higher but the energy supply from collector and the efficiency of collector are lower. So the LPG consumption is high.

Compared data between October and September, the LPG consumption in October higher when the diffuse fraction (H_d/H) is lower and other fractions are close.

Below, show example difference result between designed data and collected data in October 2005. On 20 Oct 2005 has a daily clearness index 0.4714 (47.14%). From table 3, then diffuse fraction is 65.40% so the weather condition on 20 Oct 2005 is cloudy day.

Table 17 Energy output from solar collector field and LPG consumption on 20 Oct 2005

time	η_C *	E_c* (W/m^2)	E_{cd} (W/m^2)	LPG	E_{aux} (kWh)	E_{aux-d} (kWh)
9:00:00 - 10:00:00	0.06	35.62	327.929	0.26	3.50	4.430469
10:00:00 - 11:00:00	0.27	185.50	397.44	0.00	0.00	0.428583
11:00:00 - 12:00:00	0.31	226.00	419.622	0.00	0.00	0
12:00:00 - 13:00:00	0.34	225.39	391.468	0.01	0.13	0
13:00:00 - 14:00:00	0.33	227.48	317.871	0.00	0.00	0
14:00:00 - 15:00:00	0.32	202.39	211.13	0.00	0.00	4.055109
15:00:00 - 16:00:00	0.25	104.01	90.652	0.50	6.73	9.002514
16:00:00 - 17:00:00	0.02	3.75	0	1.78	23.98	19.50857
Total		1210.13	1279.79	2.55	34.34	34.425245

*Average from every 15 minute

From Table 17 and figure 24 shows the difference of Energy supply by solar collector between data on 20 October 2005 and designing system data in October. The power supply by solar collector of collected data is close the designed data. By the maximum collector efficiency (η_C) appearing in afternoon.

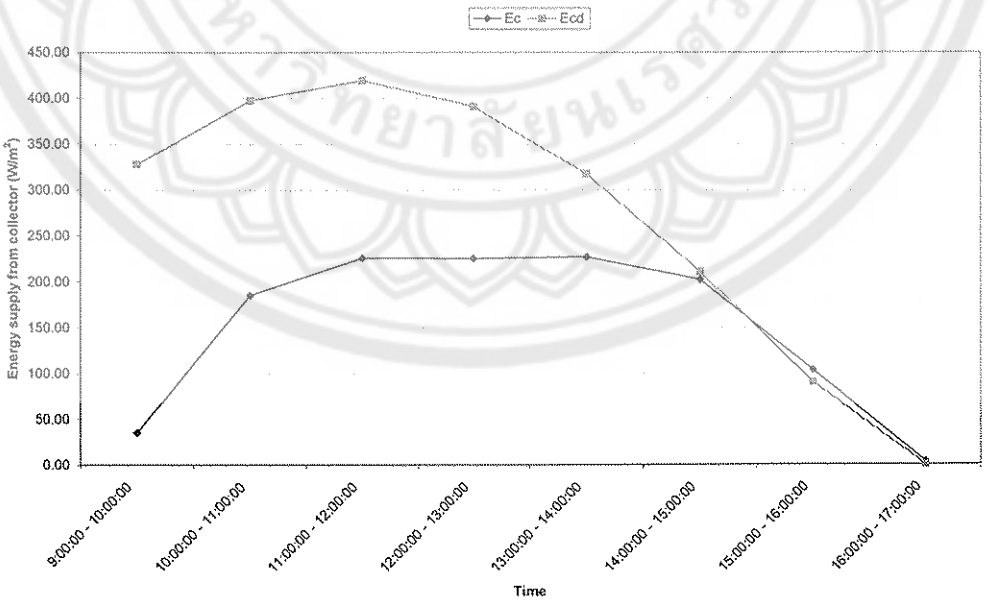

Figure 24 Energy supply by solar collector between collected data on 20 Oct 2005 and designed data in October

Cause drop of the power supply by solar collector of collected data in evening is raining. That cause drop of solar radiation and water temperature outlet collector cause heat lost.

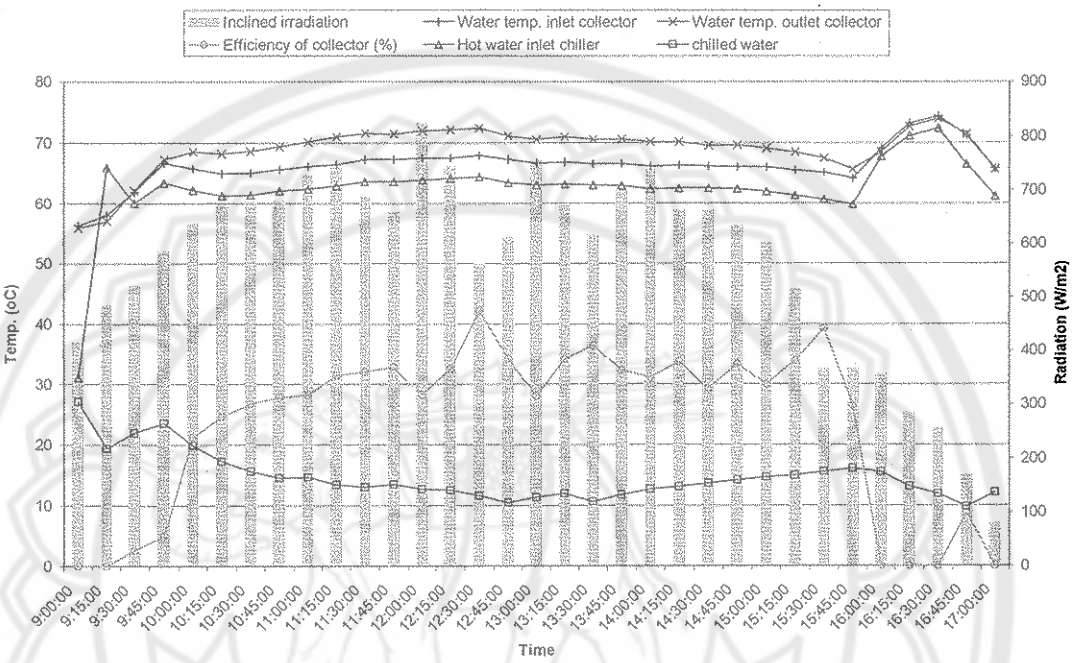

Figure 25 Energy supply by Solar collector between collected data on 20 October 2005 and designed data in October

On 20 October 2005, the mass flow rates are close value as tough under fixed mass flow rate condition, the difference of water temperature between inlet and outlet of solar collector decrease as the water temperature at inlet of solar collector increase. That reduces the energy gain and makes the efficiency of collector drops. Can see the this relationship in figure 25

The result of the water temperature outlet collector lower inlet collector on start operation system may be from remaining water in tube. For drop in evening, cause of the heat lost from exchanger at collector and tube to surrounding as low temperature from skies with cloud cover. That Supplying hot water temperature jump up at 9:15. That result from some error of the temperature sensor.

From table 17 and figure 26, although the trend of auxiliary heat consumption (LPG) is nearly, that is the LPG consumption when start the system is higher and decrease in midday until after noon it increase again. In after noon, although the both energy from collector is too closed but the LPG consumption on collected is higher because drop radiation. But in last hour has water temperature outlet from collector drop because of heat loss from raining that made high LPG consumption.

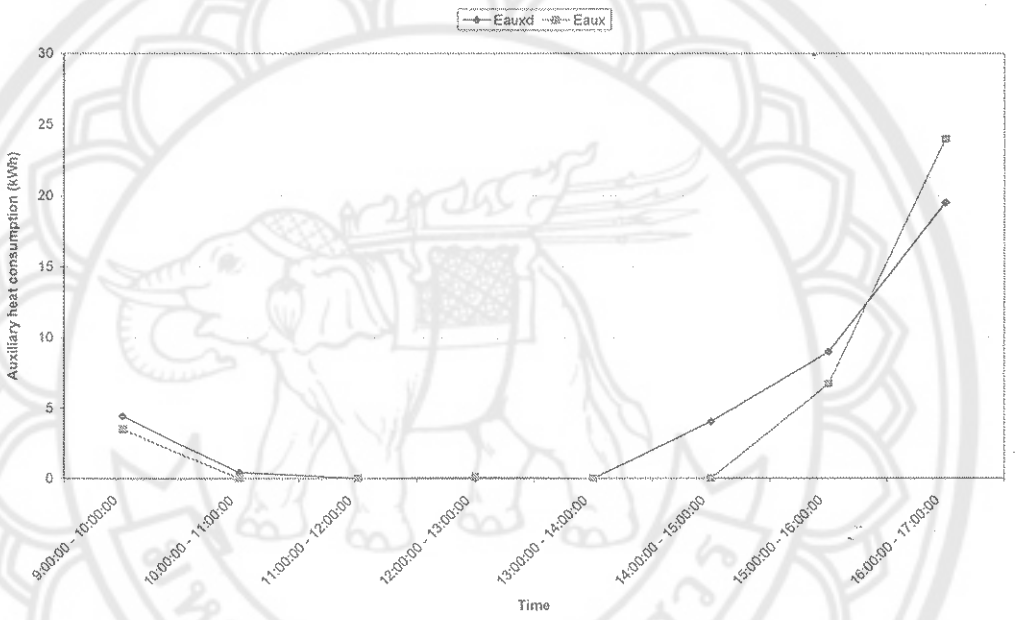

Figure 26 The auxiliary heat consumption between collected data on 20 October 2005 and designed data in October

3. The result LPG consumption and diffuse fraction in November

The average of the collected data were calculated using the equations litsted in Chapter III during measuring duration in November 2005 and 2006, and show in table 18

Table 18 The averages of data collected in November 2005 and 2006.

Item	Numerical value	Unit
Inclined irradiation (505)[1]	632.0962	W/m^2
Rate of mass flow via collector	0.8651	kg/s
Energy supply from collector (270.18)[1]	132.8378	W/m^2
LPG consumption (33.8155)[1]	7.2257	kg/day
	97.3263	kWh/day
Efficiency of collector (0.4555)[1]	0.2176	
Diffuse fraction	0.5123	

[1]Designed data

From collected data in November 2005 and Designed data in November, the result difference in September and October. Although high the inclined irradiation of collected data and the LPG consumption are higher. Because the supplying energy collector is low from low the efficiency of collector. The result of low efficiency of collector is the limitation of properties of heat transfer.

The consumption LPG in November not conversation with two last months, it over consumption than in September as lower diffuse fraction. Because of in this month, the researcher fixes the minimum water temperature inlet chiller higher than the other months (from 70°C to 75°C) for control LPG hot water heater supply heat to the chiller when water temperature lower fixed value.

Below, show example difference result between designed data and collected data in November 2005. On 4 November 2005 has a daily clearness index 0.5326 (53.26%). From table 13, then diffuse fraction is 55.35% so the weather condition on 4 November 2005 is cloudy day.

Table 19 Energy output from solar collector field and LPG consumption on 4 Nov2005

time	η_C *	E_c* (W/m^2)	E_{cd} (W/m^2)	LPG	E_{aux} (kWh)	$E_{aux\text{-}d}$ (kWh)
9:00:00 - 10:00:00	0.10	63.73	330.738	2.96	39.87	2.205257
10:00:00 - 11:00:00	0.27	185.52	405.178	0.35	4.71	0
11:00:00 - 12:00:00	0.26	217.94	429.39	0.19	2.56	0
12:00:00 - 13:00:00	0.26	204.81	397.44	0.07	0.94	0
13:00:00 - 14:00:00	0.28	230.98	317.871	0.25	3.37	0
14:00:00 - 15:00:00	0.31	208.45	203.7	0.35	4.71	2.802777
15:00:00 - 16:00:00	0.38	134.47	77.031	0.41	5.52	7.964583
16:00:00 - 17:00:00	0.22	56.73	0	1.56	21.01	17.84286
Total		1264.38	2161.35	6.14	82.7024	33.8155

*Average from every 15 minute

From Table 19 and figure 27 shows the difference of Energy supply by solar collector between data on 4 Nov 2005 and designing system data in November. The power supply by solar collector of collected data is higher after 14.00pm. By the maximum collector efficiency (η_C) appearing in afternoon.

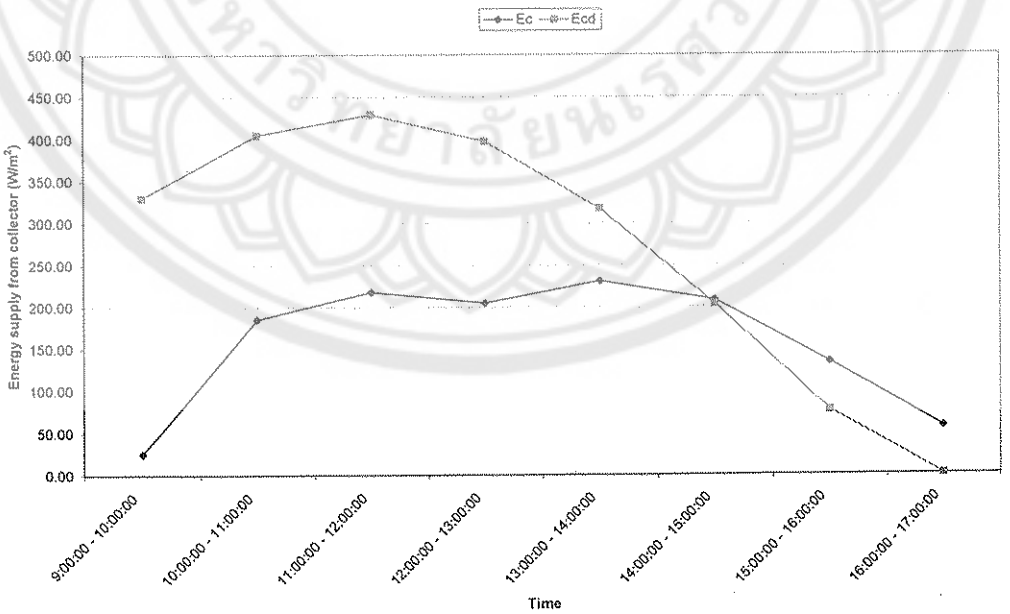

Figure 27 Energy supply by solar collector between collected data on 4 Nov 2006 and designed data in November

This day is influenced by solar radiation significantly. It means the energy supply from collector is steadily if steady solar radiation (low diffuse fraction).

On 4 Nov 2006, the mass flow rates are close value as means under fixed mass flow rate condition, the difference of water temperature between inlet and outlet of solar collector decrease as the water temperature at inlet of solar collector increase. That reduces the energy gain and makes the efficiency of collector drops. Can see the this relationship in figure 28

Following the increase of solar radiation, the efficiency of collector drops. That result from low efficiency of collector is the limitation of properties of heat transfer.

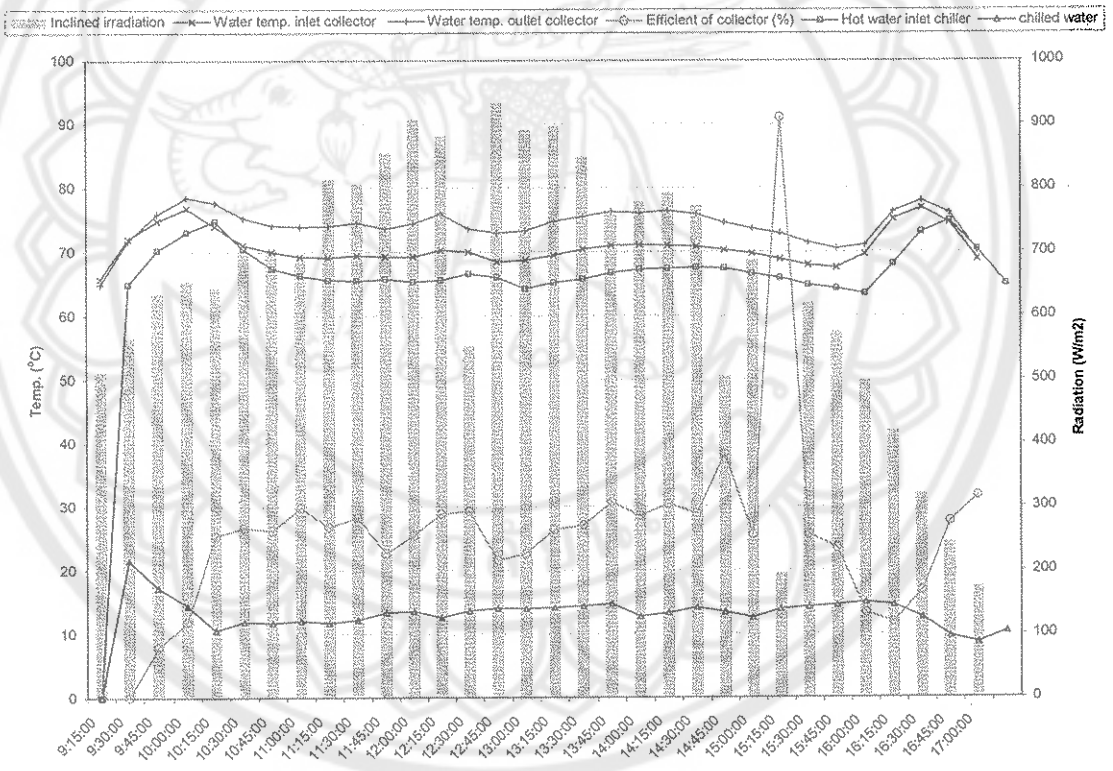

Figure 28 Energy supply by solar collector between collected data on 4 November 2005 and designed data in November

From table 19 and figure 29, On 4 Nov 2006 when start the system has high LPG consumption because the difference of water temperature between inlet and outlet of solar collector are still low and the water temperature in cold tank is not cold. In after noon, it increases again.

The result of the water temperature outlet collector lower inlet collector on start operation system may be from remaining water in tube.

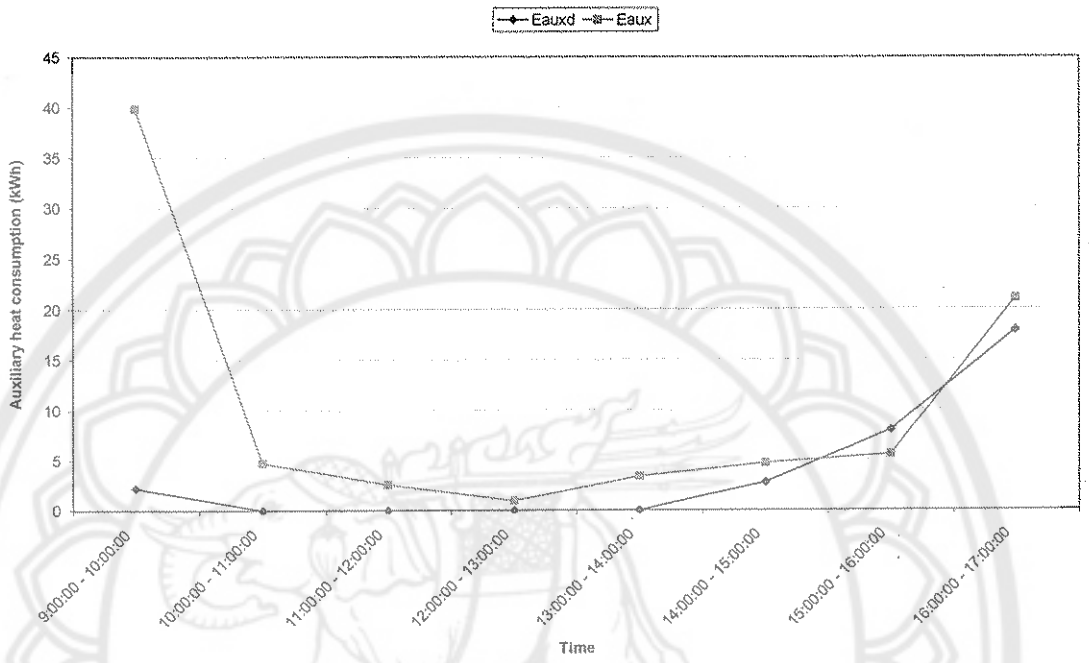

Figure 29 The auxiliary heat consumption between collected data on 4 November 2006 and designed data in November

The increasing of LPG consumption around 16.00pm is effect from the heating lag in structure building and furniture to emit the room and decreasing energy supply from collector. In collected data has used the LPG consumption all day because of the high outside temperature room so increasing the energy consumption for transfer the appearing heat in the room.

4. The result LPG consumption and diffuse fraction in December

The average of the collected data were calculated using the equations listed in Chapter III during measuring duration in December 2006, and show in table 20

Table 20 The averages of data collected in December 2006.

Item	Numerical value	Unit
Inclined irradiation (558.5)[1]	597.2741	W/m^2
Rate of mass flow via collector	0.9588	kg/s
Energy supply from collector (306.9046) [1]	198.7269	W/m^2
LPG consumption (26.19823 kWh/day) [1]	3.5933	kg/day
	46.2339	kWh/day
Efficiency of collector (0.4739) [1]	0.3349	
Diffuse fraction	0.5812	

[1]Designed data

From data between collected data in December 2006 and Designed data in December, even the inclined irradiation of collected data is higher but low the efficiency of collector. Following the increase of solar radiation the efficiency of collector drops. That result from low efficiency of collector is the limitation of properties of heat transfer.

From collected data and designed data in December, the result like in September and October. Although the inclined irradiation of collected data is higher but the energy supply from collector and the efficiency of collector are lower. So the LPG consumption is high.

Compared data between October, September and December, the LPG consumption in December is lower when the diffuse fraction (H_d/H) is lower and other fractions are close.

Below, show example difference result between designed data and collected data in October 2005. On 20 Oct 2005 has a daily clearness index 0.4714 (47.14%). From table 3, then diffuse fraction is 65.40% so the weather condition on 20 Oct 2005 is cloudy day.

Below, show example difference result between designed data and collected data in December 2006. On 6 December 2006 has a daily clearness index 0.5111(51.11%). From table 13, then diffuse fraction is 58.99% so the weather condition on 6 December 2006 is cloudy day.

Table 21 Energy output from solar collector field on 6 December 2006

time	η_C *	E_c* (W/m^2)	E_{cd} (W/m^2)	LPG	E_{aux} (kWh)	E_{aux-d} (kWh)
9:00:00 - 10:00:00	0.08	44.03	355.253	4.17	56.17	0
10:00:00 - 11:00:00	0.38	153.45	444.528	0.91	12.26	0
11:00:00 - 12:00:00	0.34	199.16	480.376	0.81	10.91	0
12:00:00 - 13:00:00	0.35	269.11	453.12	0.03	0.40	0
13:00:00 - 14:00:00	0.36	273.44	370.336	0.02	0.27	0
14:00:00 - 15:00:00	0.36	240.80	246.72	0.56	7.54	0.318194
15:00:00 - 16:00:00	0.39	194.45	104.904	0.48	6.47	8.158606
16:00:00 - 17:00:00	0.38	101.89	0	1.18	15.89	17.72143
Total		1476.24	2455.24		8.1600	109.9107

*Average from every 15 minute

From Table 21 and figure 30 shows the difference of Energy supply by solar collector between data on 6 December 2006 and designed data in December. The power supply by solar collector of collected data is higher after 14.30pm. That is the auxiliary heat consumption in this period time is lower. By the maximum collector efficiency (η_C) appearing in afternoon that difference designed data as in midday. This day is influenced by solar radiation significantly. It means the energy supply from collector is steadily if steady solar radiation (low diffuse fraction).

On 6 December 2006, the mass flow rates are close value as tough under fixed mass flow rate condition, the difference of water temperature between inlet and outlet of solar collector decrease as the water temperature at inlet of solar collector increase. That reduces the energy gain and makes the efficiency of collector drops. Can see the this relationship in figure 31

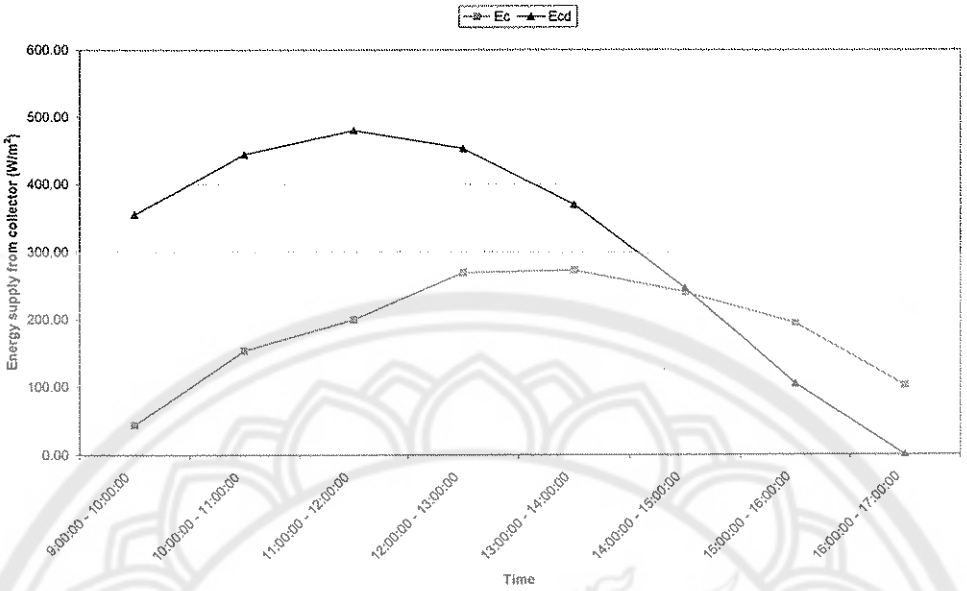

Figure 30 Energy supply by solar collector between collected data on 6 Dec 2006 and designed data in December

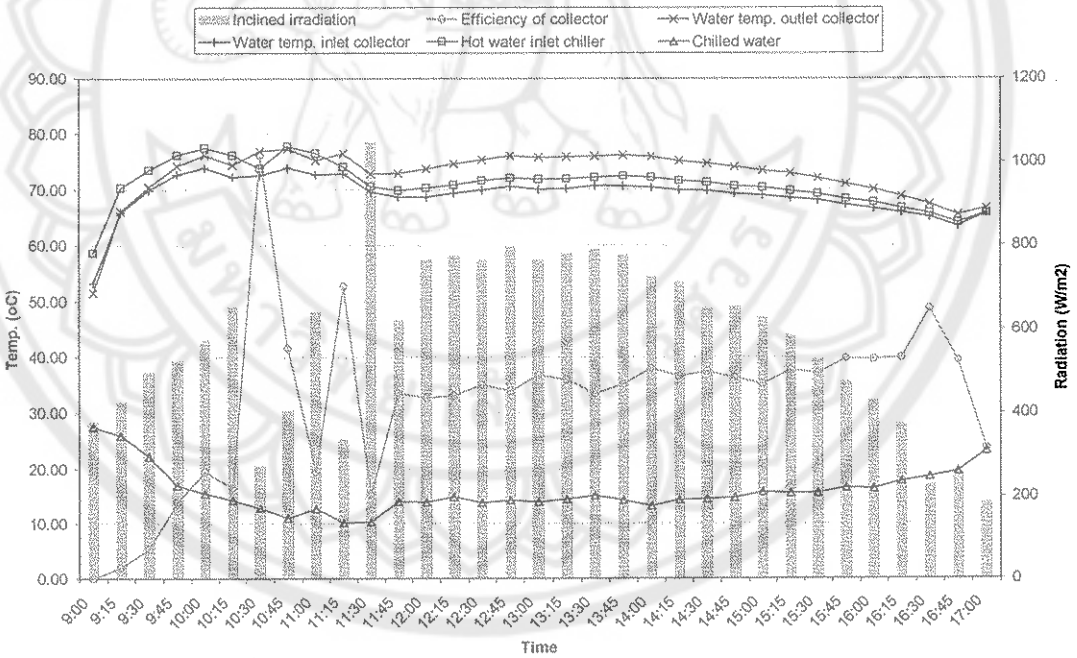

Figure 31 Energy supply by solar collector between collected data on 6 December 2006 and designed data in December

On 6 Dec 2006 when start the system has high LPG consumption because the difference of water temperature between inlet and outlet of solar collector are still low and the water temperature in cold tank is not cold. In after noon, it increases again.

The result of the water temperature outlet collector lower inlet collector on start operation system may be from remaining water in tube.

The jump of efficiency of collector at 10.15-11.30. That result from diffuse radiation.

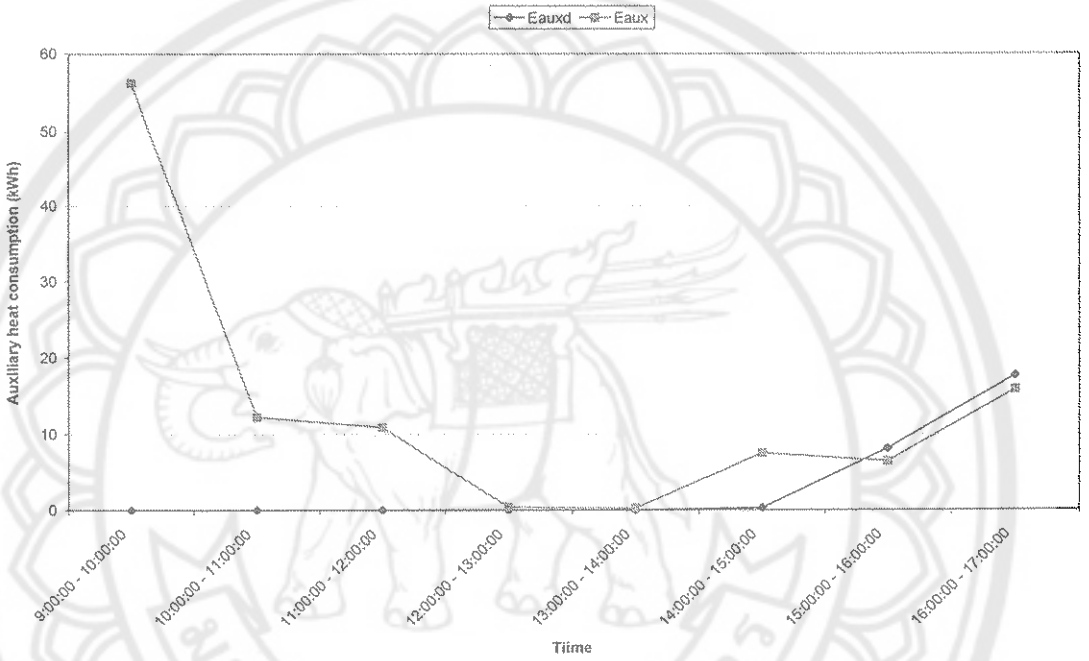

Figure 32 The auxiliary heat consumption between collected data on 6 December 2006 and designed data in December

From table 21 and figure 32, the LPG consumption of collected data in morning, that is higher may be it result from water temperature in clod is high (27.85°C) and hot tank is lower (58.67°C, the energized by heat medium at 70°C to 95°C for absorption cycle). In after noon it raise again. But the LPG consumption on designs is higher rate consumption in afternoon because the energy supply from collector on 6 December 2006 is higher.

The raise of LPG consumption in afternoon is effect from the heating lag in structure building and furniture to emit the room and decreasing energy supply from collector. In collected data has used the LPG consumption all day because of the high

The raise of LPG consumption in afternoon is effect from the heating lag in structure building and furniture to emit the room and decreasing energy supply from collector. In collected data has used the LPG consumption all day because of the high outside temperature room so increasing the energy consumption for transfer the appearing heat in the room.

5. The result LPG consumption and diffuse fraction in January

The average of the collected data were calculated using the equations litsted in Chapter III during measuring duration in January 2006 and 2007, show in table 22

Table 22 The averages of data collected in January 2006 and 2007.

Item	Numerical value	Unit
Inclined irradiation (617.3750)[1]	619.9229	W/m^2
Rate of mass flow via collector	0.9549	kg/s
Energy supply from collector (345.3095)[1]	163.0385	W/m^2
LPG consumption (1.6196 kWh/day)[1]	0.035	kg/day
	0.4714	kWh/day
Efficiency of collector (0.5063)[1]	0.2510	
Diffuse fraction	0.5840	

[1]Designed data

From collected data in January 2006 – 2007 and Designed data in January, the inclined irradiation, the energy supply from collector and the efficiency of collector of designed data is higher but higher the LPG consumption because of the efficiency of collector in real operation appear in afternoon, not noon same designed data, as directly the heating emit period of building to surrounding (about 2.00 – 4.00 pm). The increasing of the efficiency of collector in this period can decrease the LPG consumption from increasing of energy supply by collector. And insulation of both storage tanks (hot and

cold water) can help decreasing energy consumption at the moment time. Beside in collect data, Air temperatures are low so the energy consumption in the conditioning is few too.

Below, show example difference result between designed data and collected data in January 2006 – 2007. On 10 Jan 2007 has a daily clearness index 0.5224 (52.24%). From table 13, then diffuse fraction is 57.10% so the weather condition on 10 Jan 2007 is cloudy day.

Table 23 Energy output from solar collector field on 10 Jan 2007

time	η_C *	E_c* (W/m^2)	E_{cd} (W/m^2)	LPG (kg)	E_{aux} (kWh)	$E_{aux\text{-}d}$ (kWh)
9:00:00 - 10:00:00	0.07	30.6992	352.9360	0.0000	0.0000	0
10:00:00 - 11:00:00	0.18	97.3139	461.1680	0.0100	0.1347	0
11:00:00 - 12:00:00	0.33	208.3055	515.5650	0.0000	0.0000	0
12:00:00 - 13:00:00	0.33	245.3677	505.4410	0.0000	0.0000	0
13:00:00 - 14:00:00	0.34	260.4025	433.6400	0.0100	0.1347	0
14:00:00 - 15:00:00	0.33	239.5266	311.2200	0.0000	0.0000	0
15:00:00 - 16:00:00	0.34	206.3265	165.0660	0.0000	0.0000	5.283474
16:00:00 - 17:00:00	0.34	129.3736	17.4400	0.0100	0.1347	16.53216
Total		1417.3155	2762.4760	0.0300	0.4041	21.81634

*Average from every 15 minute

From Table 23 and figure 33 shows the difference of Energy supply by solar collector between data on 10 Jan 2007 and designed data in January. The power supply by solar collector of collected data is higher after 15.00pm. That is the auxiliary heat consumption in this period time is lower. By the maximum collector efficiency (η_C) appearing in afternoon that difference designed data as in midday. This day is influenced by solar radiation significantly. It means the energy supply from collector is steadily if steady solar radiation (low diffuse fraction).

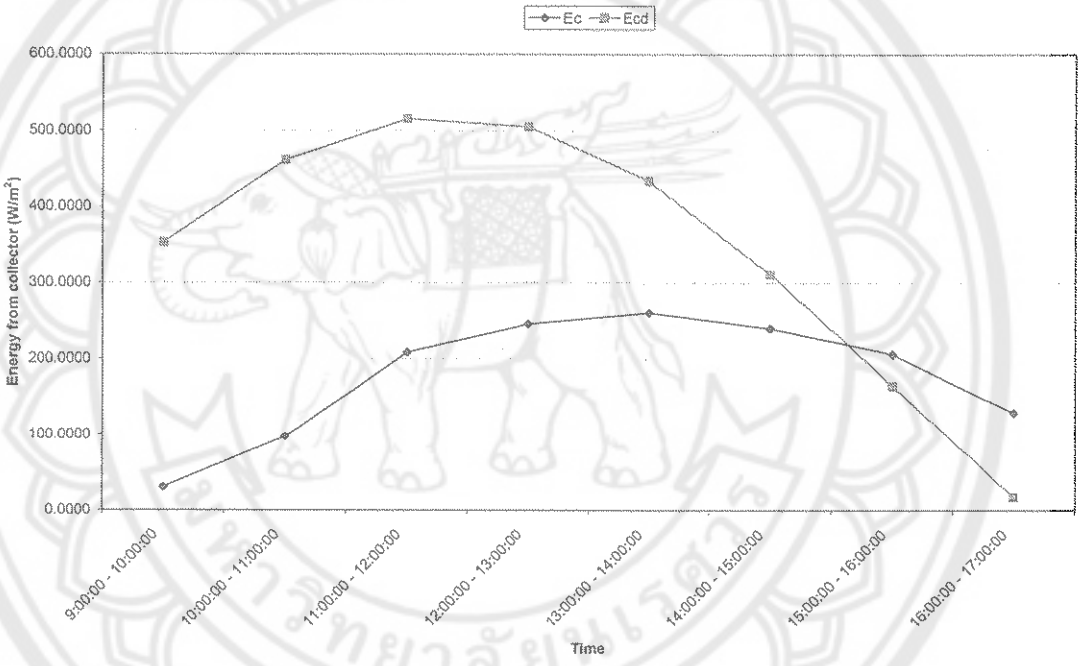

Figure 33 Energy supply by Solar collector between collected data on 10 Jan 2007 and designed data in January

On 10 Jan 2007, the mass flow rates are close value as tough under fixed mass flow rate condition, the difference of water temperature between inlet and outlet of solar collector decrease as the water temperature at inlet of solar collector increase. That reduces the energy gain and makes the efficiency of collector drops. Can see the this relationship in figure 34

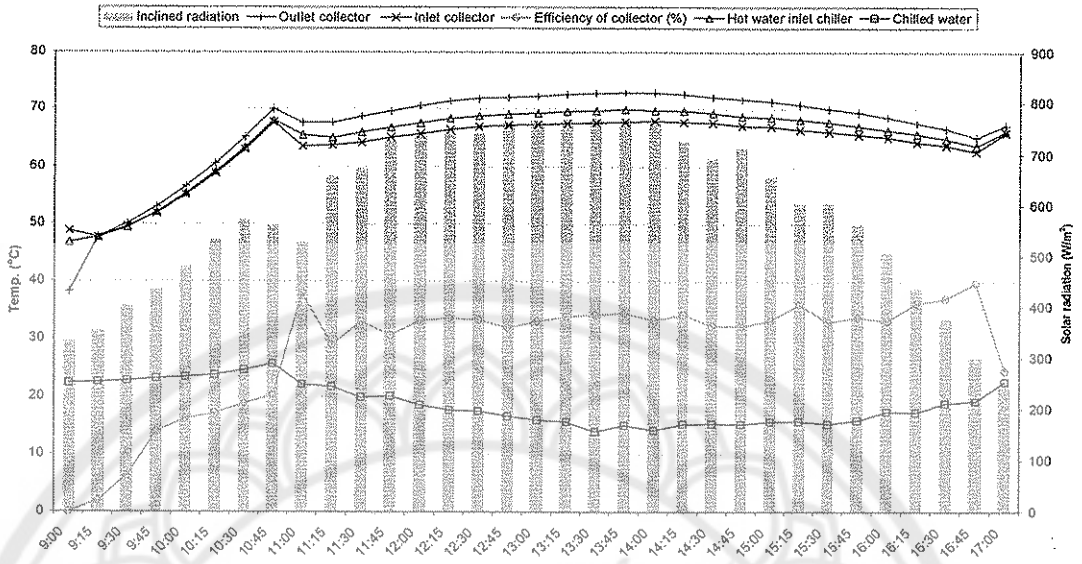

Figure 34 Energy supply by Solar collector between collected data on 10 Jan 2007 and designed data in January

The result of error in the temperature on start operation system may be from remain water in tube.

Figure 35 The auxiliary heat consumption between collected data on 10 Jan 2007 and designed data in January

From table 23 and figure 35, we see the difference between LPG consumption of collected data on 10 Jan 2007 and designed data in January all day. Its have many difference in after noon. Because of the energy supply from collector of collected data is higher in after noon as direct the maximum energy demand period for decreasing room temperature. And low the air temperature all day, so used energy for transfer heat through out the room is lower too as wall as energy from collector is enough.

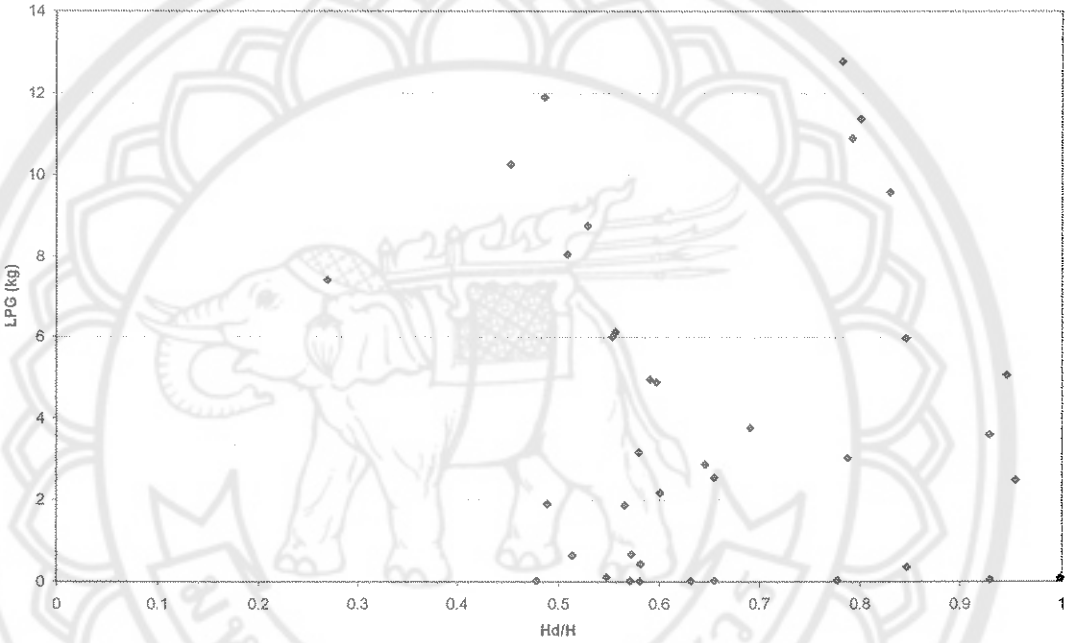

Figure 36 Diffuse radiation (H_d/H) and LPG consumption

Figure 36 shows The variations of LPG consumption following the diffuse radiation (H_d/H).

If solar radiation is constant, The LPG consumption is low when low Hd/H. the low LPG consumption for the system from collected data is the most appear in Hd/H at 20-80%. And the maximum LPG consumption is appear in Hd/H at 80-100%.