CHARTER IV

RESULT AND ANALYSIS

The results and analysis chapter consists of two sections. The first section shows the technical performance of Solar Absorption Cooling System at SERT. The second section shows the economic analysis of the system.

The performance of the system

A solar-powered air conditioning system has been installed at SERT, in Naresuan University.

The system employs the evacuated heat pipe collector area of 72 m^2. The designed cooling capacity is 10 cooling ton.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 20 seconds.

The averages of the collected data were calculated using the equations listed in chart III during measuring duration from November 16, 2006 to December 15, 2006, and shown in table 3

Table 3 The averages of data collected from November 16, 2005 to December 15, 2005.

Item	Numeric value	Unit
Inclined Irradiation	551.87	W/m^2
Rate of mass flow via collectors	0.96	kg/s
Rate of mass flow via generator	2.05	kg/s
Rate of mass flow Via evaporator	1.79	kg/s
Energy supply (Qg)	179.5	kW
Cooling load (Qe)	24.61	kW
Consumptions of electricity of pumps	38	kWh/day
Consumptions of LPG	2.56	kg/day
Efficiency of solar collector	0.37	-
Cooling COP	0.11	-

A single day of normal operation is defined as a day when sunshine is sufficient and the system works steadily. Since this study collected many days of data over a month period. But this system had been installed some months ago, it runs unsteadily frequently. So there are just nineteen days data can be used to analyze. However the results of analysis still are desirable to optimize the performance of this system further because the application of air conditioning depend on daily conditions very much. Therefore only 1 day was selected to show the relationship of each parameter in the system. The selected day is 6 December 2005, which had the best data for analyze and did not have any auxiliary energy supplied. All energy came from solar radiation.

The relationships of each parameter on this day in the system are shown below.

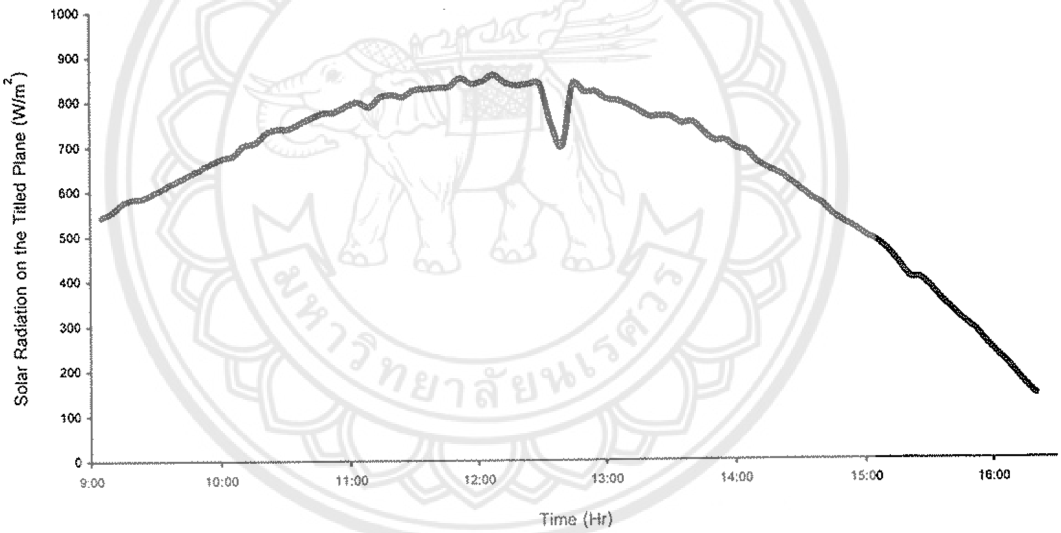

Figure 8 Solar irradiation on the titled plane on December 6, 2005

In Figure 8, the solar irradiation incident on the collectors is shown during the time of measure.

The Figure 9, shows relation between supplying hot water temperature and chilled water temperature. As the feeding temperature increased, the parameter which underwent significant variation was the temperature of the chilled water at outlet of Evaporator which, as expected, noticeably dropped. The minimum of the chilled water temperature ever was at 7 °C. Supplying hot water temperature jump up at 13:10.that result from some errors of the temperature sensor.

On the other hand, May two reasons resulted in the both of starting temperature are too close:

1. The heat lost from both of hot tank and cold tank too much.
2. The system did not run continuously, no heat was stored in the tanks from previous days.

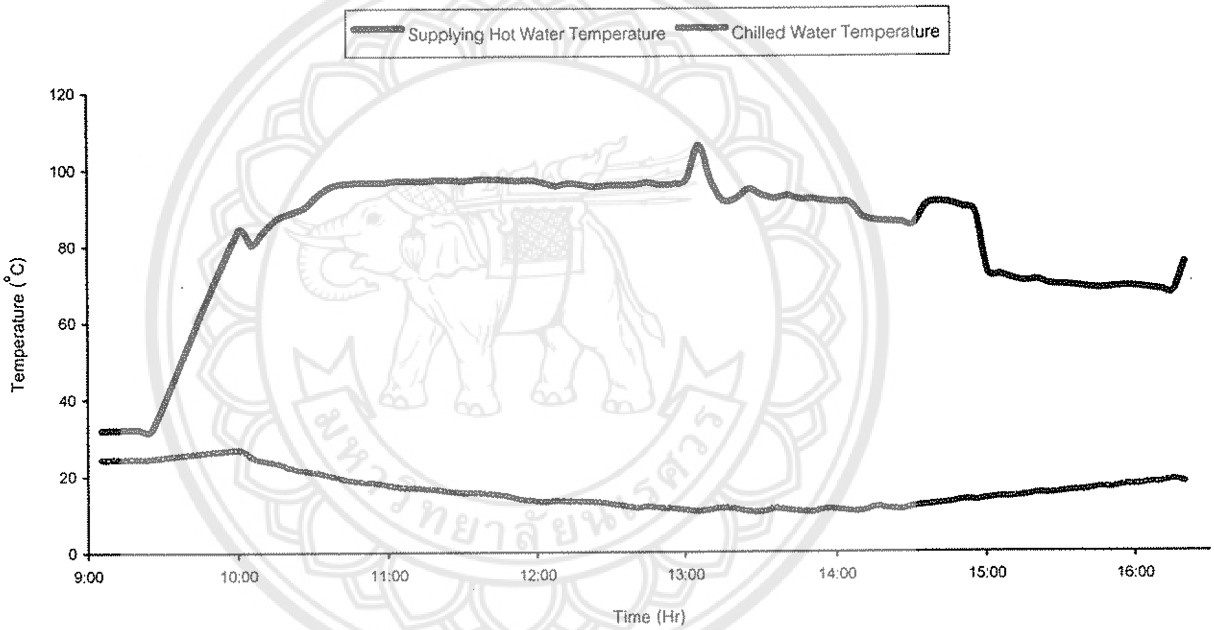

Figure 9 Supplying hot water temperature and Chilled water temperature

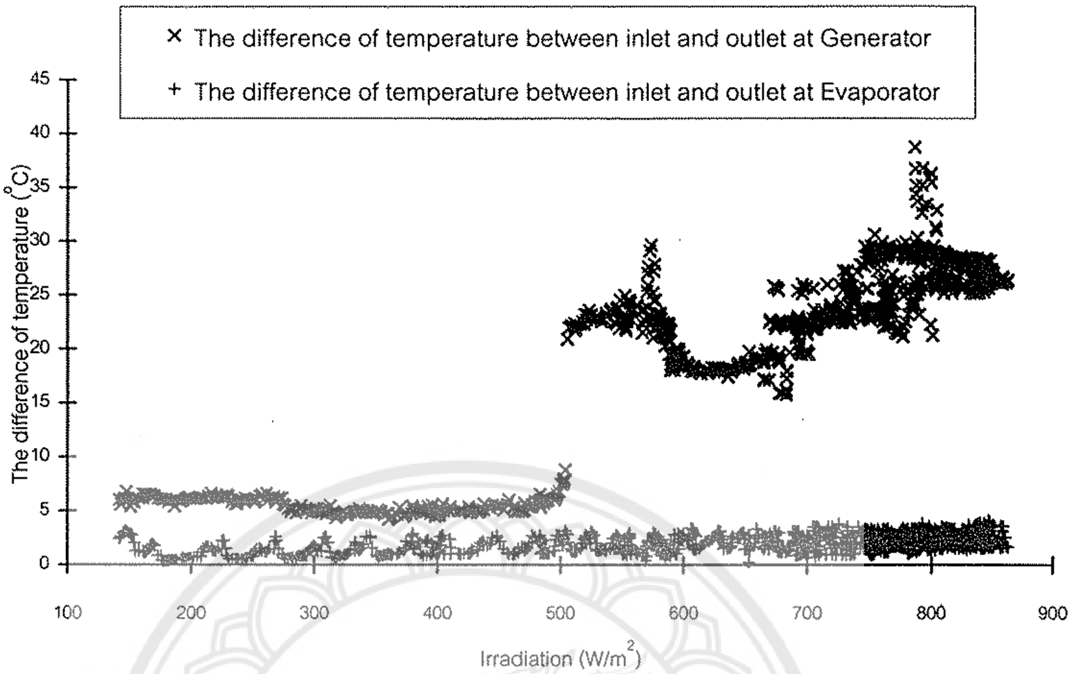

Figure 10 The difference of inlet and outlet temperature at Generator and Evaporator

The figure 10 shows the difference of temperature between inlet and outlet at Generator and Evaporator. When solar irradiation increases, the difference of temperature at Generator varied significantly. But no significant variation was detected at the difference of temperature at Evaporator. The average of the difference of temperature at Evaporator is 1.88 °C

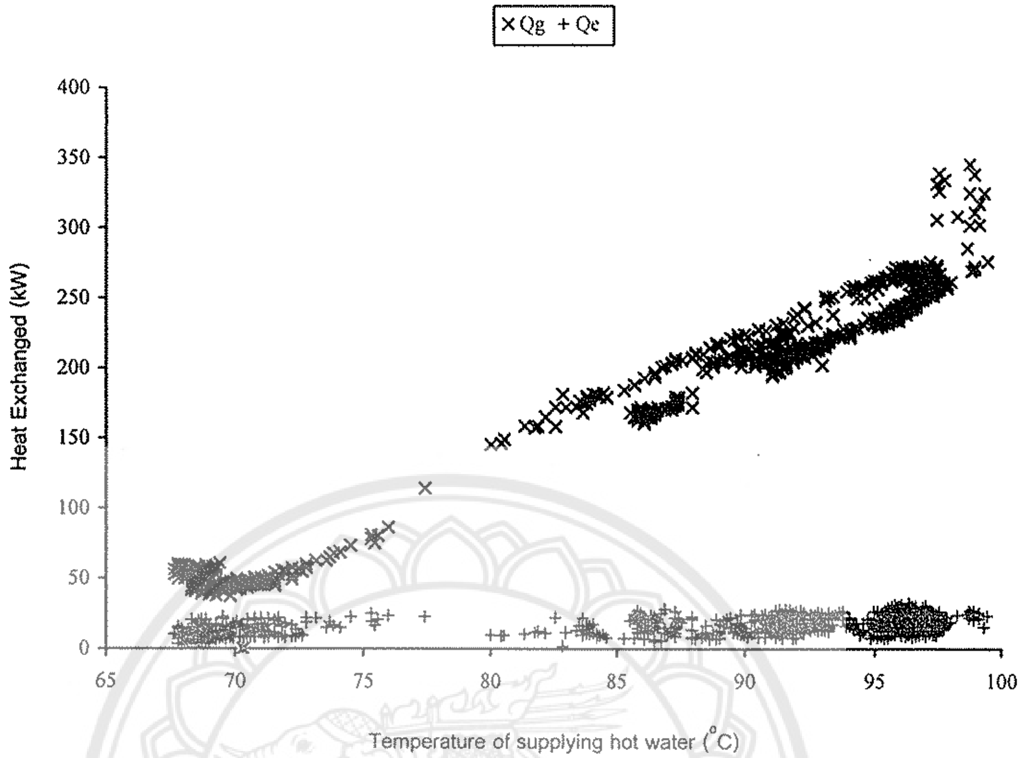

Figure 11 Heat exchanged at Generator Q_g and Evaporator Q_e VS supplying hot water temperature

Figure 11 shows the variations of heat exchanged at Generator and Evaporator, Q_g andQ_e Following the temperature of supplying hot water.

Q_g varied with the temperature of supplying hot water significantly and when the temperature approached a higher range, Q_g dropped decreasingly. Because the absorption cycle is energized by a heat medium (hot water) at 70°C to 95°C, Q_g became to be very low level while the temperature of supplying hot water is lower than 75°C.

However, Q_e always kept at a constant level approximatively. The Q_e is not affected by the temperature of supplying hot water. May that result from the effect of the cold tank.

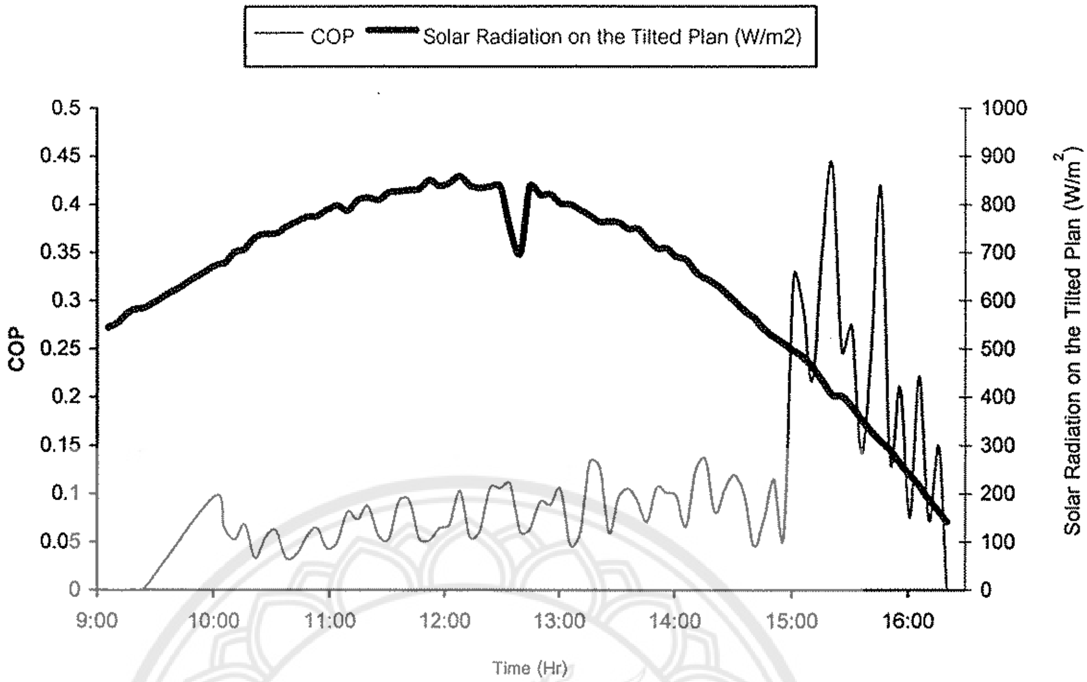

Figure 12 Variations of the COP and Radiation

Figure 12 shows the relationship between Coefficient performance of chiller and irradiation. The cooling COP increased slightly when irradiation increases. The maximum value of the COP appeared at afternoon because the temperature of supplying hot water dropped while irradiation decreased, that made Q_g decreased, so the cooling COP (the ratio of the heat exchanged at Evaporator to the heat exchanged at Generator) became to be higher.

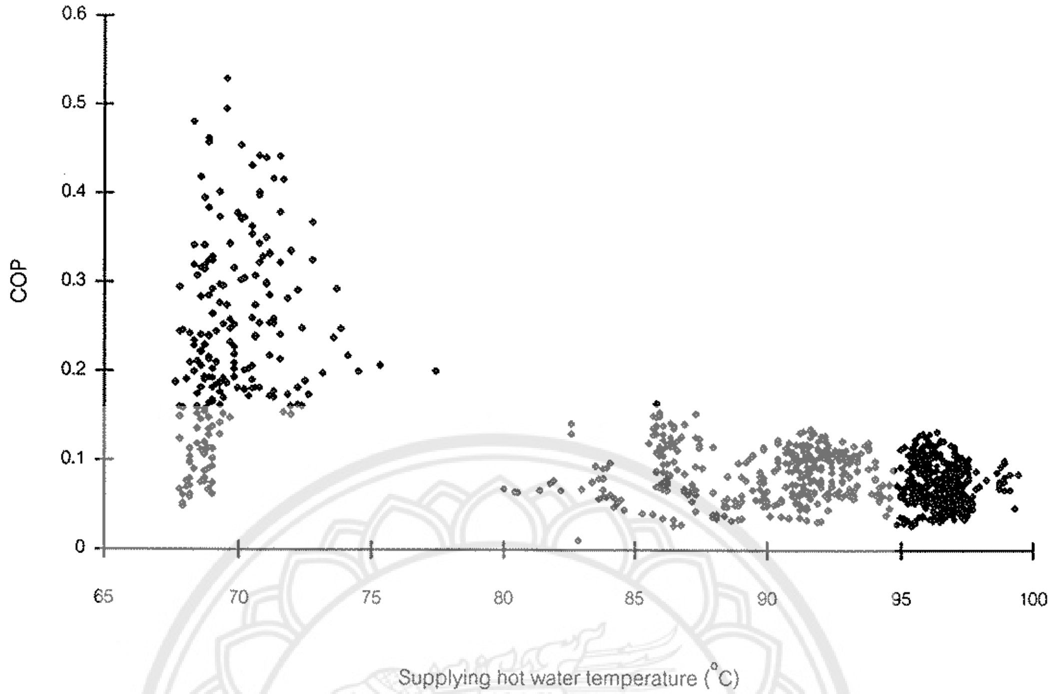

Figure 13 The variation of the cooling COP with the temperature of supplying hot water

Figure 13 shows the relation between the cooling COP and the temperature of supplying hot water. The analysis of the performance shows how, once the minimum feeding temperature about 70 °C is exceeded, the COP decreases even if the refrigerating power (Q_e) still maintain constant. The poor performance is partially due to the limitation caused by the use of water from the pipes to cool the machine. i.e. some partial Q_g were released off pipes and Generator. Since Q_e was constant approximatively (shown in Figure 11), the higher supplying hot water temperature was corresponding with higher numeric value of Q_g (shown in Figure 11). So COP (the ratio of Q_e to Q_g) decreased.

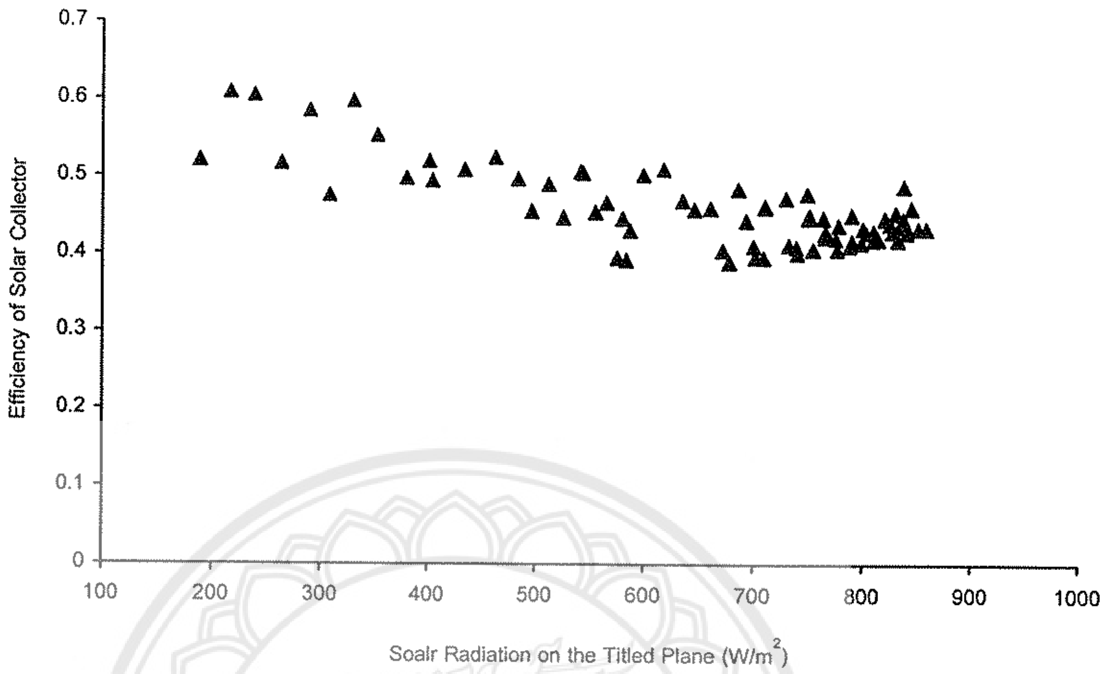

Figure 14 Efficiency of collector and irradiation

Figure 14 shows that the efficiency of collectors unit is not influenced by solar radiation significantly. It means the solar collectors unit works steadily. Following the increase of solar radiation the efficiency of solar collector drops. That results from the limitation of properties of heat transfer. Under fixed mass flow rate condition the difference of water temperature between inlet and outlet of solar collector (ΔT) decreases as the water temperature at inlet of solar collector increases. That reduces the energy gain and makes the efficiency of solar collector drops.

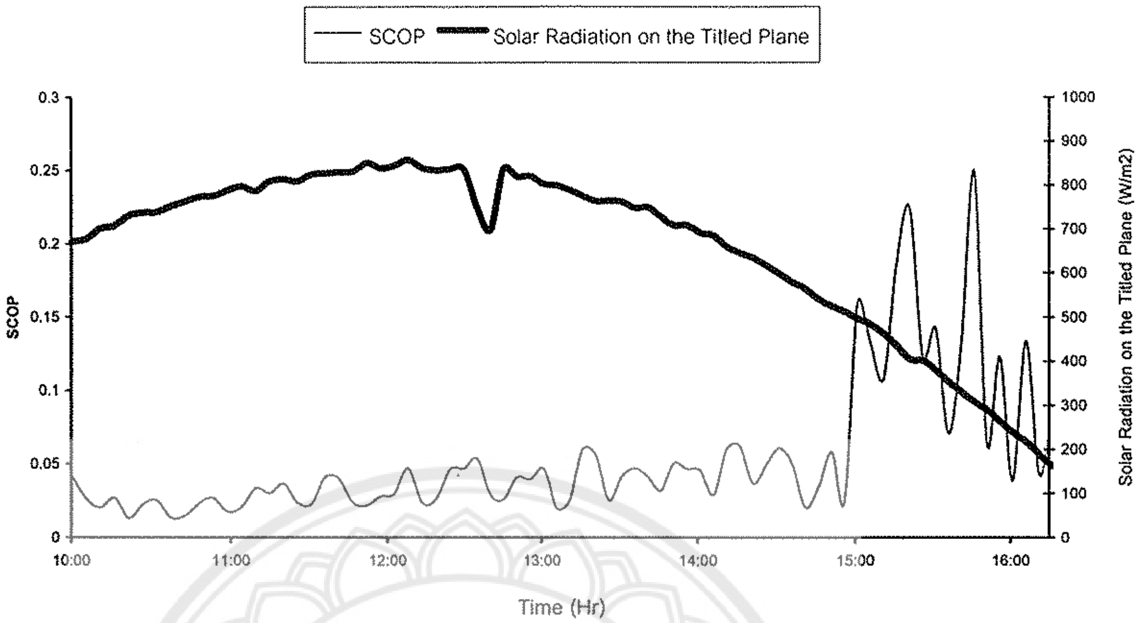

Figure 15 The overall coefficient performance of the solar absorption cooling system

The Figure 15 shows the SCOP (the overall coefficient performance of the solar absorption cooling system) has the same varying stream with the cooling COP. The average of SCOP is about 0.051.

Economic analysis

In this section, the results of economic analysis using payback period and the yield of cooling load costs were shown.

Calculation

Some of the simplifying assumptions made are as fellows:

1. Life time of the chiller and heat pipe collectors is 10 years (Those were guarantied by company)

2. No expendable components and materials are needed to be replaced, thus no maintenance costs. However, in case some replaceable parts break up, like vacuum heat pipe tubes, thus maintenance cost was set annually at 0.05% of the capital cost.

3. Operation cost consists of the consumptions cost of electricity and LPG per year.

4. The system monthly runs 22 days

Where:

The capital cost is consist of

Heat pipe collectors cost	=	960,162 Baht
Absorption chiller cost	=	1,402,971 Baht
Cooling water unit cost	=	31,870 Baht
Heater backup cost	=	57,406 Baht
Total capital	=	2,452,409 Baht

Discount factor was yielded by equation (3–14) on varying discount rate;

NPV of each year = (Capital cost + Operation cost) x discount factor

Total NPV = sum of NPV of each year during analysis period

Operation costs were consist of costs of electricity costs and LPG costs, was calculated under varying electricity price.

Maintenance cost = Capital cost x 0.05%

Salvage cost = Capital cost x Salvage rate

Both of them were calculated under decreased the price of heat pipe solar collector tube during the analysis period.

Benefits

The benefits of the SACS at SERT come from the energy saving, which are directly electricity saving.

Energy saving per year = Chiller cooling capacity 10 (cooling tons) x 12,000 Btu/hr / 10.6 (ERR Btu/hr/kW) x 8 hours x 22 days x 12 months = 13,877.43 kWh/year

Energy saving cost per year = Energy saving per year x Price of electricity

Payback period = Total NPV/Energy saving cost per year (year)

Yield of Cooling load = Total Cooling load / Total NPV (kWh/Baht)

Payback period, Yield of cooling load on increasing price of electricity and decreased heat pipe solar collector tube during analysis period were shown following figures.

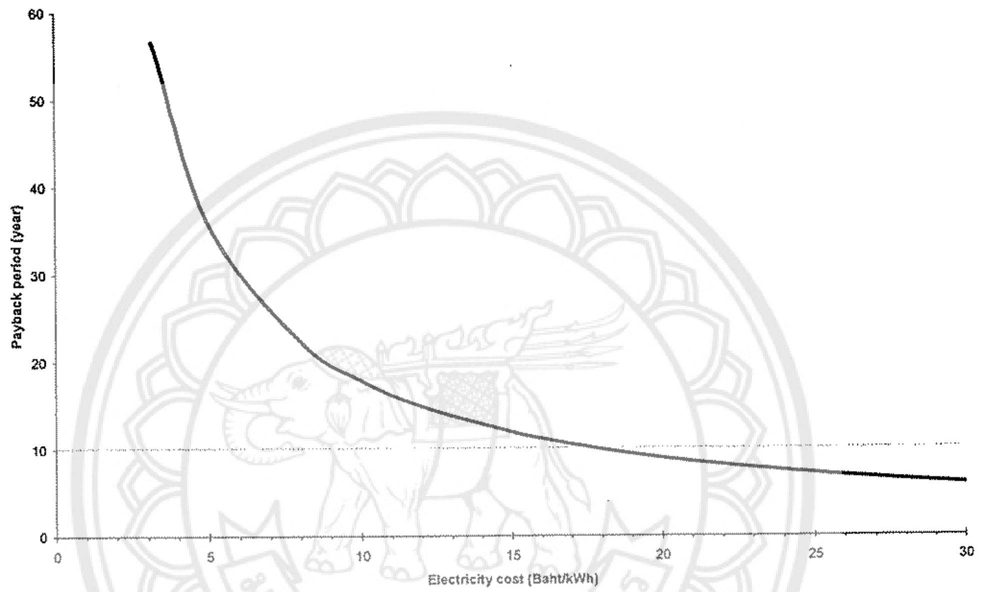

Figure 16 Payback period on increasing electricity price

Figure 16 shows the payback period deceased nonlinearly as the price of electricity increases during analysis period. That results from increased cost of the total energy saving.

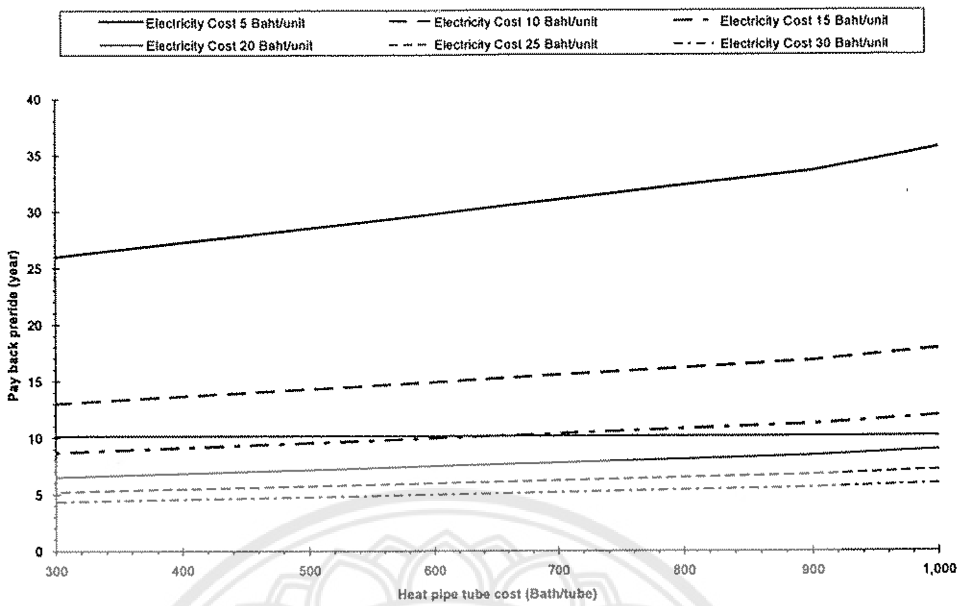

Figure 17 Payback period on both effects of increasing electricity price and decreased heat pipe solar collector tube price

Figure 17 shows that electricity cost is major factor to impact payback period. On the other hand, the effect of decreasing heat pipe cost is not significant.. From the energy price situation, the trends of energy price will be increasing rapidly in near future. So the economic advantage of using solar cooling system will be competitive compared with conventional cooling system.

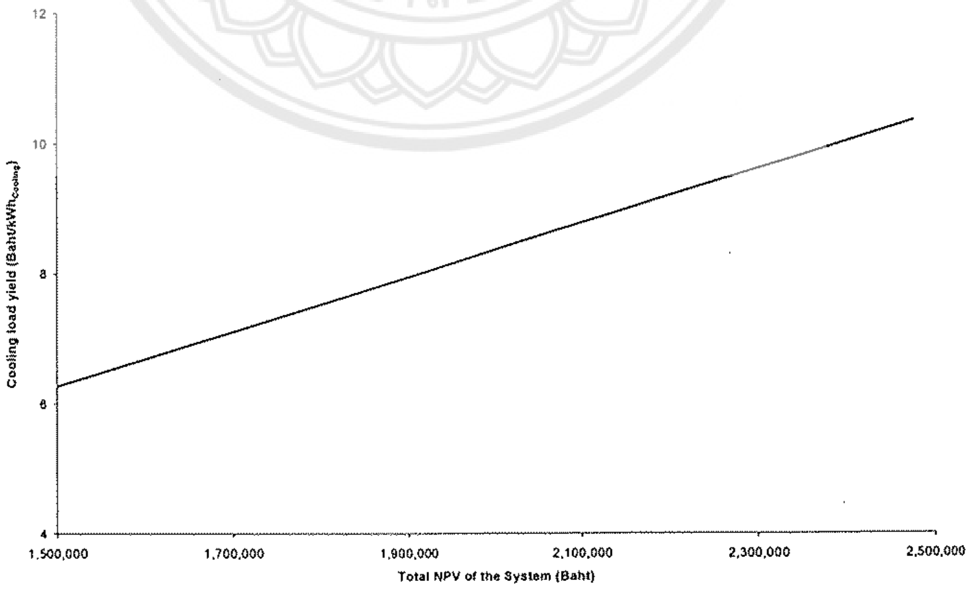

Figure 18 Cooling load yields per unit cost

Figure 18 shows that cooling load generated by the system per unit capital cost are increased as the capital cost decrease due to technology developing and mass production of the system and components.