5 ECONOMIC AND FINANCIAL

5.1 ECONOMIC OF SOLAR THERMAL SYSTEM

Economic viability is crucial to development of solar thermal market. Above all barriers that have hindered the market growth, high cost of solar systems has been a major cause that shun potential users from its environmental benefits and energy cost saving. While there is no general guideline or proven records of how solar thermal systems save energy available to public, leave the customers only information source to suppliers who sometime are new to the technology as well. In this chapter, we will outline some of the criteria that make the solar thermal systems' economic feasible.

Solar thermal systems generally have high first cost and low operating cost. The initial cost of solar system can be minimized by proper sizing system's main components which are collectors and tanks to the optimum size that delivers energy at the average demand. A system that design at full load may be oversize for applications that have seasonal demand. For example, hotels have low hot water demand during low tourist season. A system that design to serve full load would be too large when the hotel has only half of the occupancy rate in low season. It is recommended that users measure their hot water consumption for at least one year in order to understand their actual demand for proper sizing for solar thermal systems.

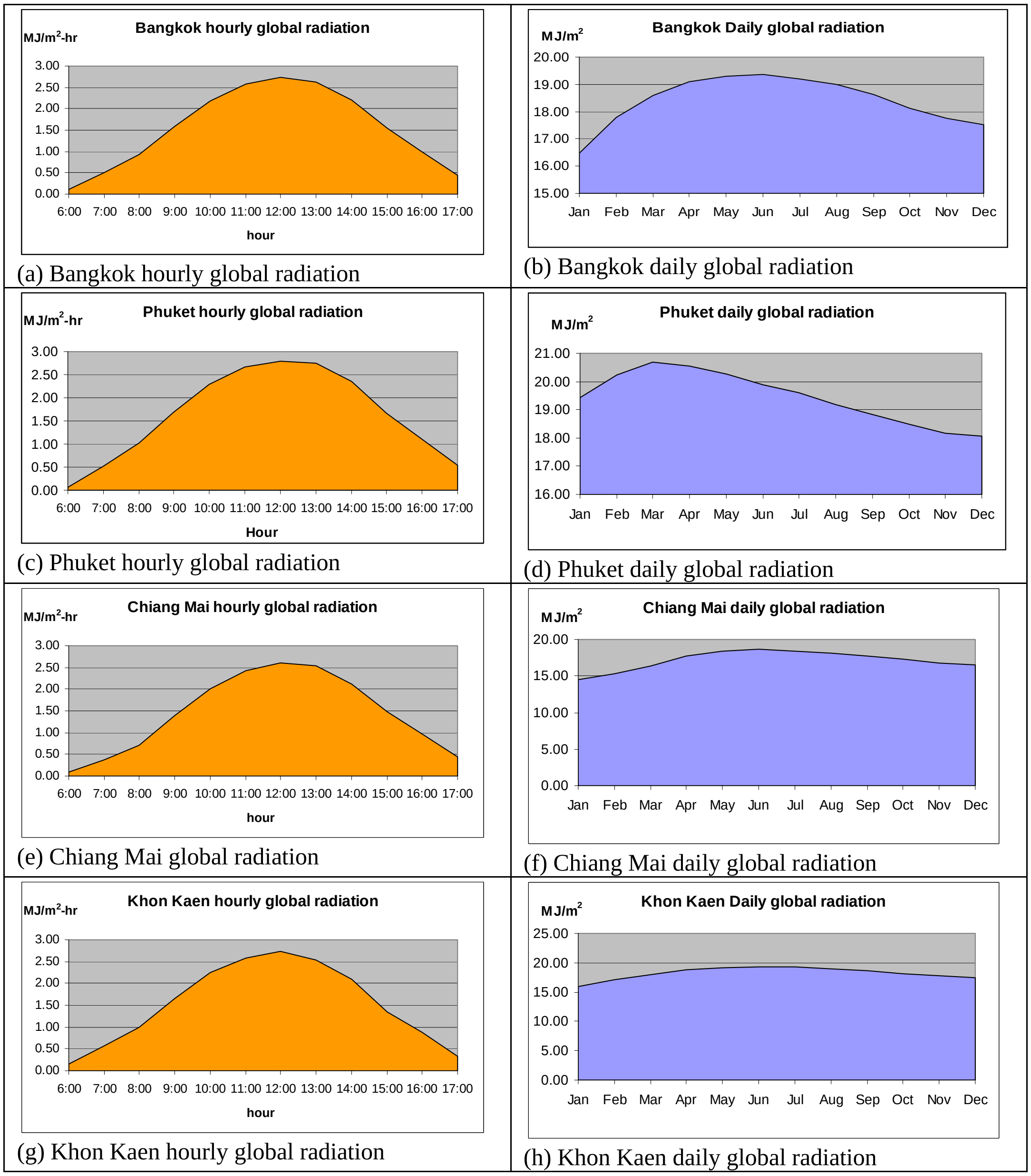
Solar thermal system performance associates with quality of installation, solar radiation, type of collector, and maintenance. A good installation can greatly increase the system efficiency which means more energy produced and more positive cash flow that shorten the pay back period. Regular maintenance can extend the system lifetime and increase life cycle cost saving.

Below outline some of the criteria for design and optimization of solar thermal systems.

5.1.1 Solar radiation

Thermal performance of solar system is determined by solar radiation, ambient temperature, and heat losses from collectors, storage tanks and pipes. As heat losses can be prevented by good insulation, system performance is primarily influenced by solar radiation. Thailand has an average global solar radiation at 4.5-4.7 kWh/m^2 per day with seasonal fluctuation within ±20% of the average value.

Although annual solar gain is higher than the economic profitability figure as compare to countries in higher latitudes, Thailand solar radiation is affected by tropical monsoon. Applications which demand occurs during monsoon season are less suitable for solar thermal systems. For example, manufacturing of canned agricultural products, large quantity of hot water is needed to make syrup and containers washing. However, as some fruit and vegetable are harvested during this time of the year, solar system can not economically providing heat source in this agro sector. As shown in Figure 5.1, Phuket daily global radiation is highest during the first quarter of the year and lowest during the monsoon months in the second half of the year. Chiang Mai and Khon Kaen, although peak radiation is lower, the solar radiation is relatively constant throughout the year. In understanding seasonal variation of the energy source, solar thermal system can be design to properly serve heat demand throughout the year with least investment cost.



(a) Bangkok hourly global radiation

(b) Bangkok daily global radiation

(c) Phuket hourly global radiation

(d) Phuket daily global radiation

(e) Chiang Mai global radiation

(f) Chiang Mai daily global radiation

(g) Khon Kaen hourly global radiation

(h) Khon Kaen daily global radiation

Figure 5.1 Solar radiation in Bangkok, Phuket, Chiang Mai and Khon Kaen

5.1.2 Load pattern and continuity of demand

The most suitable application for solar thermal is when the demand occurs during daytime and operation is continuous all year round. Residential and commercial applications have hot water demand in the morning and evening hours, thus require storage tank that increase the system cost. Some applications in industrial sector can integrate solar thermal system directly into the existing process.

5.1.3 Working temperature and types of collector

With weather condition in Thailand, applications that require temperature below 70°C can use low cost, non-concentrated or lower efficiency collectors. Typical temperature required for hot water demand in residential and commercial applications and water feed to boilers in industrial application is around 50-60°C, this temperature level can be served by flat plate or evacuated tubes collectors typically sold in Thailand. Table 5.1 shows a comparison of energy produced from 3 types of collectors; unglazed, flat plate and evacuated tubes using simulation from a software tool, T-Sol®, to simulate performance of solar collectors under weather conditions in 4 major cities representing 4 regions in Thailand (central, north, northeast, and south). The energy produced is in the range of 1,000-1,300 kWh/m^2 for water temperature demand at 60°C which shows that at low temperature, efficiency of collector is not a key factor. Users should select the most cost effective collectors according to demand temperatures.

Table 5.1: Energy produced by 3 types of collectors for water at 60°C

Weather data	kWh/m^2		
	Unglazed	**Flat plate**	**Evacuated**
Bangkok	1,134	1,237	1,312
Chiang Mai	1,052	1,218	1,308
Khon Kaen	1,078	1,193	1,264
Phuket	1,057	1,173	1,243

5.1.4 Solar fraction

Solar fraction is a percentage or portion of annual energy demand meet by solar energy. A hundred percent solar fraction means that all of the energy demand is supplied by solar system. However, larger size of solar system requires higher investment cost. Proper solar fraction that uses least investment cost while gives highest performance is the key to economic viability for large solar thermal systems.

F-chart method is generally used for the analysis for an optimum size of solar collector and tank. From Duffie and Beckman (1991), the optimum collector area can be determined by plotting the solar fraction to the annual thermal performance. The optimum area is where the slope of thermal performance is $P_2C_A/P_1C_{F1}L$.

$$\frac{\partial f}{\partial A_C} = \frac{P_2 C_A}{P_1 C_{F1} L} \qquad \textbf{Equation 5-1}$$

Where

f = fraction of solar energy to annual heat load

A_c = collector area

P_1 = ratio of the life cycle fuel cost savings to the first year fuel cost savings

P_2 = ration of the life cycle expenditures incurred because of the additional capital investment to the initial investment

C_{F1} = first year fuel cost without a solar system

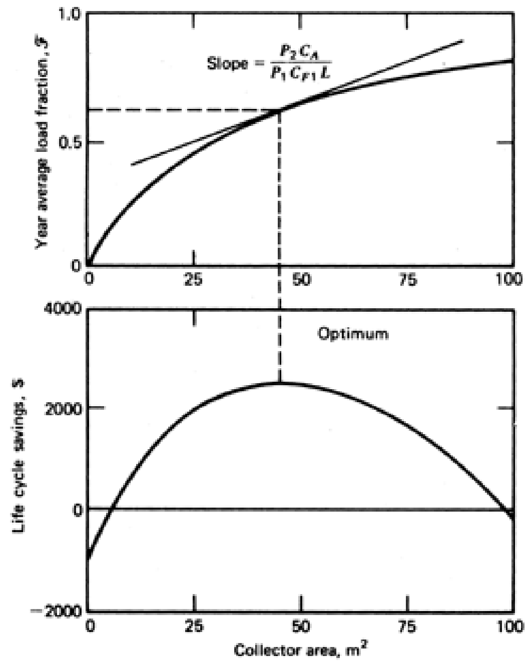


Figure 5.2 Optimum collector area determination from the slope of the *f* Vs A_C thermal performance curve. From Duffie and Beckman (1991).

The analysis use life cycle cost method which takes into account all future expenses. The method provides a means of comparison of future costs with today's costs by discounting all anticipated costs to present worth value. Detail of the analysis involves complicated mathematic equations. Alternately, we use software tools that can perform the economic analysis. Two simulation software tools are used in this study, Retscreen®, developed by Retscreen International Clean Energy Support Center, Natural Resource Canada and T-Sol®, developed by Dr. Valentin EnergieSoftware GmbH. Both of the software gives similar results when simulate with the same parameters. Only T-Sol® gives more graphical results in technical analysis while Retscreen® accommodates more in the economic details.

Using T-Sol®, results of simulation for a hotel (100 guestrooms, double occupancy) are shown in Figure 5.3 and Figure 5.4. Storage tank size 1000, 3000, and 5000 liters are compared for the least solar collectors required to achieve solar fraction at 60%.

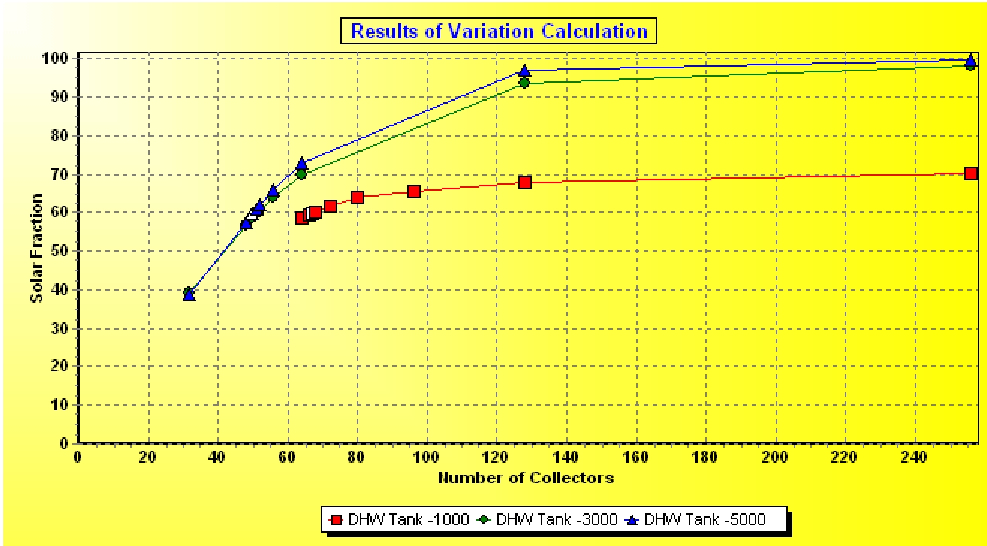


Figure 5.3 solar fraction and number of solar collectors

The simulation shows that at 60% solar fraction, 3,000-liter and 5,000- liter systems require only 50 solar collectors while 1,000 liter tank system needs nearly 70 collectors to achieve the same solar fraction. As larger number of collectors gain higher solar fraction, however, the incremental of heat gain is not linear. After 70% of solar fraction, the system yield only 20% more with double the number of collectors. Therefore, the solar fraction at 60% is mostly recommended for cost effectively implementation of solar thermal systems.

Since system cost is largely determined by the size of solar collector and storage tank. A small tank may cost lower but the system would require larger number of collectors while a larger tank may cost more but require less collectors. Designers should be cautious in cost comparison for the optimum size of tank and collectors. Design results of the 3 tank sizes are compared in Figure 5.4. Systems with 3,000 and 5,000-liter tanks yield similar system efficiency and number of collectors. Selection of system sizes is to be decided by cost comparison between the 2 systems

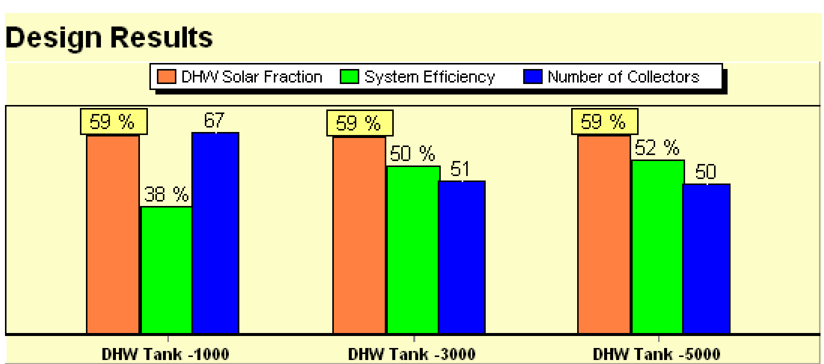
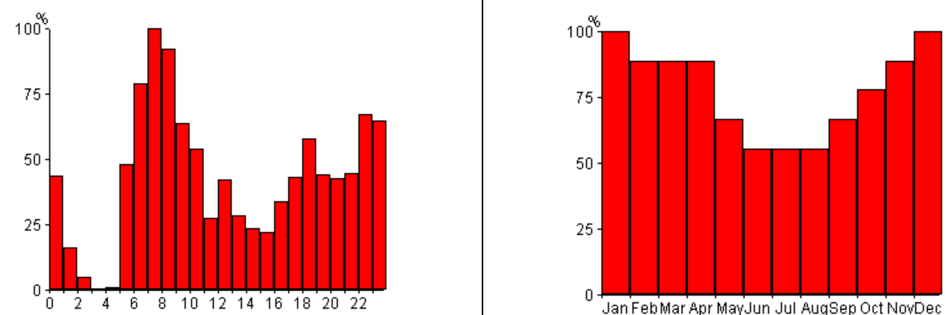


Figure 5.4 A comparison of system efficiency and tank sizes

Based on our survey to existing solar hot water systems in hotels, most of the systems were design at 90-100% solar fraction. System installed in hotels during 1986-1988 cost approximately 8,000 – 10,000 Baht/m^2 of collector area. More recent installations during 1990's cost were between 17,000 – 18,000 Baht/m^2.

Table 5.2 shows economic analysis for 3 solar hot water systems. Two systems installed in 1987 and 1988, and another system installed in 2003. Since there is no record of actual hot water consumptions, the economic analysis shown here is based on simulations with typical load profile for hotels in Thailand.

1) Hot water demand is 100 liters/room/day for double occupancy.
2) Room occupancy rate is 70%.
3) Hotel annual hot water demand is based on Thai tourist season as shown in Figure 5.5.



(a) Daily load profile

(b) Annual load profile

Figure 5.5 Load profile for typical hot water demand in Thai hotels

Simulation results show that all of the three systems have solar fraction nearly 100% resulting in the high investment cost and pay back periods nearly 10 years.

When simulate system performance for solar fraction at 60% and assume system costs were proportion to the number of collectors, pay back period for the optimized design could be minimized to 5 years for replacing electricity and 8 years for LPG.

It should be noted that hotel 1 and 2 installed solar systems nearly 20 years ago. The costs of systems and price of electricity were of those during that time.

Table 5.2 Review of Existing Installation and proposed optimized design

System	Hotel 1	Hotel 2	Hotel
Location	South	Northeast	North
Year of Installation	1988	1987	2003
Annual solar irradiation	1,711.76 kWh/m^2	1,895.71 kWh/m^2	1,970.49 kWh/m^2
Collector type	Flat plate	Flat Plate	Flat Plate
Collector efficiency	70%	70%	75.5%
Collector annual Solar gain	499 kWh/m^2	988 kWh/m^2	1,176 kWh/m^2
Number of collectors	60	45	48
Storage volume	8,000 liter	8,000 liter	10,000 liter
Hot water demand	4,000 liter/day	3,500 liter/day	6,500 liter/day
Type of fuel	Electricity	Electricity	LPG
Annual fuel saving	51,298 kWh	55,518 KWh	8,760 kg
Solar fraction	98.9 %	97.8%	94.6 %
Fuel price	1.7 Baht/kWh (in 1988) escalation 3%/year	1.7 Baht/kWh (in 1987) escalation 3%/year	16.5 Baht/kg
Investment cost	960,000 Baht	800,000 Baht	1,680,000 Baht
Net present value	2,210,473Baht	1,545,988 Baht	2,473,157 Baht
Pay back period	10 years	8 years	10 years
Proposed size of solar system for optimum investment			
Solar fraction	60.1%	58.8%	62%
Number of solar collectors	18	14	24
Investment cost	256,000 Baht	248,888 Baht	840,000 baht
Pay back period	5 years	5 years	8 years

5.2 PAY BACK PERIOD

For commercial and industrial applications, solar water heater is considered as an auxiliary heat source to conventional heating system. Businesses invest in the solar system anticipate to the future conventional fuel cost saving. While least cost analysis should be performed for the optimum investment to the energy deliver, conventional fuel cost savings indicate return on investment of the solar system.

The initial investment cost is mostly associated with cost of the solar system to meet with the annual loads in supplemental to conventional fuel. Operating cost, fuel cost and system maintenance is considered negative cash flow and the energy produced from the solar system is accounted for revenue generated.

The initial cost of solar water system in Thailand is relatively high as compare to other countries. Low annual turnover of the solar companies due to low sell volume has driven solar companies to mark up high price on the products in order to cover for company expenses.

Domestic hot water system cost approximately 29,000 baht/m^2. Locally produced flat plate collectors system cost lower than imported products and Chinese evacuated tubes collectors cost similar to local flat plate collectors. The solar systems sold during the year 2000 cost around 35,000 Baht for the same specification, a nearly 10% increase of the domestic system price.

Table 5.3 A market survey of domestic solar hot water system cost in 2007

Domestic SHW	Flat plate					Evacuated tube	
	Local 1	**Local 2**	**Local 3**	**Import 1**	**Import 2**	**Import 3**	**Import 4**
Collector	2.16 m^2	2.0 m^2	2.02 m^2	1.9 m^2	2.3 m^2	15 tubes	20 tubes
Tank	160 liters	200 liters	200 liters	160 liters	150 liters	200 liters	165 liters
Cost (Baht)	49,000	53,000	57,500	57,300	96,000	48,000	39,000
Installation	8,000	-	-	-	-	5,000	5,000
VAT 7%	3,990	3,710	-	4,000	-	3,710	3,080
Total	60,990	56,710	57,500	61,300	96,000	56,710	47,080
Cost/m^2	28,236	28,355	28,750	32,263	41,739	28,355	23,540

The cost of solar system for commercial applications is slightly lower than those in the domestic application. Size of installation is varied from 10 – 100 m^2 and the system cost is in a range of 17,500 – 27,500 Baht/m^2. The variation of the prices among different solar companies does not seem to have a pattern whether it is based on the size of system or the quality of materials. Although local products tend to have lower prices, the price quotes are rather arbitrary as customers can not easily compare the price for large systems. The average and more consistent cost is 23,000 Baht/m^2. With reference cost of system in the year 2000, locally produced system cost increase on average of 6% over the last 6 years.

Table 5.4 A market survey for cost of Solar System in Commercial application in baht/m^2

Year	Local 1	Local 2	Local 3	Import 1	Import 2
2000	14,000	-	-	-	-
2007	17,500	27,500	23,400	22,936	32,000

A cost breakdown for commercial solar systems in the table below shows that solar collectors make up for approximately 60% of the total cost.

Table 5.5 Solar system cost breakdown in percentage of total cost in commercial applications

Item	Cost	%
1. Collectors	13,000 – 15,000 Baht/m^2	50 – 60%
2. Tanks (size 3,000 – 5,000 liters)	150,000 - 300,000 Baht (depends on material and tank size)	20 – 30%
3. Balance of System (pump, control, pipe etc) and installation	Estimated at 20-30% of the materials cost	20 – 30%

Most of Thai solar hot water buyers make cash payment. Tax incentives and financing scheme for solar system are not yet available. Return on investment can be relatively straightforward calculated based on the initial cost and fuel saving with the fuel price escalation over the lifetime of the system.

Pay back period, the time needed for the cumulative savings to equal the initial investment, is the term that is most common used and comprehensible among Thai solar customers and general public. Economic factors such as inflation and fuel escalation are taken into consideration for the calculation of pay back periods. With initial cost of solar system at 29,000 Baht/m^2 for domestic and 23,000 Baht/m^2 for commercial and industrial applications and with the economic parameters below, the pay back periods are calculated as shown in Table 5.6.

Key economic indicators

- GDP 5% (average over the year 2000-2006[1])
- Inflation 3.5% (average over the year 2003-2006[2])

Fuel cost	Electricity (Baht/kWh)	LPG (Baht/kg)	Fuel Oil (Baht/liter)
2000	2.5	9	8.5
2007	3.9	16.7	17.5
Average % increase/year	8%	10%	10%

1 www.bot.or.th

2 Inflation Report 2006, Bank of Thailand

Table 5.6 Pay back periods of solar thermal system for each sector

Sectors	Pay back periods (years)			Remark
	Electricity	LPG	Fuel Oil	
Residential	5-6	-	-	
Commercial	3-5	7-8	6-8	
Industrial	-	-	4-8	Depends on types of collectors and hot water demand. Pay back period at 4 years is calculated based on unglazed collector's pre-heat feed water to boilers.

For optimized design variables, pay back periods for solar thermal system are in the range of 3-8 years. Thailand cost of solar system is relatively high while electricity cost is relatively low as compare to other countries that have success installation of solar water heater. Prices and typical size of domestic solar water heater in Table 5.7 are summarized from the Sun in Action II report of ESTIF, Thailand data came from our market survey. There are several factors contributed to the pay back periods. The next section in Sensitivity Analysis will discuss of factors that have impact to the pay back periods of the solar systems.

Table 5.7 Country comparison for pay back periods of DSHW

Country	Baht/m^2	Typical size Collector-tank	Total (Baht)	Electricity (Baht/unit)	Pay Back Period
Japan	25,450	2x2 m^2 - 200 liter	101,800	7.3	8
Thailand	29,000	2 m^2 - 160 liter	58,000	3.9	6.2
Spain	25,000	2 m^2 - 200 liter	50,000	11.5	3.5
Italy	17,500	4 m^2 - 200 liter	70,000	10	3.5
Israel	11,800	2.5 m^2 - 150 liter	29,500	4.85	3.5
Greece	14,750	2.4 m^2 - 150 liter	35,400	3.8	3.6
China	7,150	2 m^2 - 180 liter	14,300	1.8 - 5	2.5 - 6

5.3 SENSITIVITY ANALYSIS

There are several economic factors that have impact to year-to-positive cash flow or pay back time. Analysis of the impacts lead us to more understanding of how pay back time can be shorten to an acceptable range among Thai investors and what sort of financial measures are needed to achieve the target. There are 3 parameters selected for sensitivity analysis: the amount of energy produced from solar system, the initial costs and the annual operating costs. All are analyst within 40% sensitivity range using Retscreen®.

<u>Parameters for simulation</u>
Application: Hotel
Load: Hot water for 180 Rooms, 70% occupancy rate
Fuel replaced: Electricity 3.9 Baht/kWh escalation at 8%/year
Collector: 22 collectors, Glazed, efficiency 78%
Tank: 5,000 liter
Solar fraction: 58%

<u>Simulation results</u>
- RE delivered 27.24 MWh
- Initial cost 1,006,940 Baht
- Annual cost 1,520 Baht (pump running cost)
- With the electricity cost at 3.9 Baht/kWh, pay back period is 3.4 years.

Using a typical hotel application for the sensitivity analysis, the results are shown in the next page. With the same fuel cost at 3.9 baht/kWh, reducing initial cost 20% from its original cost resulted in pay back time at 2.8 years. Further reduction to 40%, the pay back period can be greater decrease to 2.1 years. While increasing RE energy delivered which can be done by using higher efficiency collectors or higher number of collectors can decrease the pay back time to only 2.5 years. This shows that initial cost is the key parameter to reducing the pay back time.

Table 5.8 Sensitivity Analysis for Year-to-positive cash flow

Electricity						
		Avoided cost of heating energy (THB/kWh)				
RE delivered (MWh)		2.3400	3.1200	**3.9000**	4.6800	5.4600
		-40%	-20%	0%	20%	40%
16.34	-40%	7.9	6.3	5.3	4.5	4.0
21.79	-20%	6.3	5.0	4.1	3.5	3.1
27.24	0%	5.3	4.1	**3.4**	2.9	2.5
32.68	20%	4.5	3.5	2.9	2.4	2.1
38.13	40%	4.0	3.1	2.5	2.1	1.8
		Avoided cost of heating energy (THB/kWh)				
Initial costs (THB)		2.3400	3.1200	**3.9000**	4.6800	5.4600
		-40%	-20%	0%	20%	40%
604,164	-40%	3.4	2.6	2.1	1.8	1.6
805,552	-20%	4.4	3.4	2.8	2.4	2.0
1,006,940	0%	5.3	4.1	**3.4**	2.9	2.5
1,208,328	20%	6.1	4.8	4.0	3.4	3.0
1,409,716	40%	6.9	5.5	4.5	3.9	3.4
		Avoided cost of heating energy (THB/kWh)				
Annual costs (THB)		2.3400	3.1200	**3.9000**	4.6800	5.4600
		-40%	-20%	0%	20%	40%
912	-40%	4.1	3.7	3.4	3.1	2.9
1,216	-20%	4.1	3.7	3.4	3.1	2.9
1,520	0%	4.1	3.7	**3.4**	3.1	2.9
1,824	20%	4.1	3.7	3.4	3.1	2.9
2,128	40%	4.1	3.7	3.4	3.1	2.9

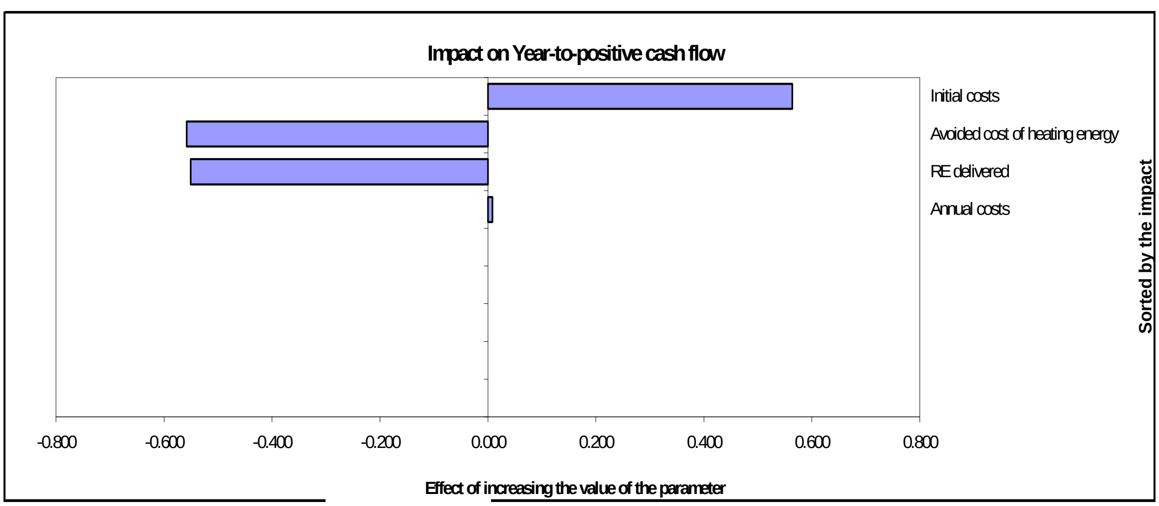


Figure 5.6 Effect of increasing the value of the parameter

Although replacing electric water heater with solar water heater in residential application has a long pay back period of 6.2 years, the same fuel replacement in commercial application require only 3.4 years. This is partly due to lower cost of collectors in larger systems and higher hot water demand in commercial application.

As compare to countries where solar thermal technology is successfully implemented, Thailand pay back time for DSHW is relatively long because the initial cost is high while fuel price particularly electricity is low. Since change of fuel price will have impact to the country economic, left the initial cost of solar system the only option that we can interfere. Table 5.9 compares variation for the percentages of initial cost reduction. For the current domestic solar system cost at 29,000 Baht/m^2 (or 58,000 Baht for a system), pay back period is 6.2 years for replacing electricity. In order to make solar systems more appealing to customers, pay back time should not be longer than 5 years. Hence a 30% reduction of initial cost is needed for the economic feasibility in domestic hot water heater.

For commercial applications, replacing electric water heater in hotel/hospital can already be feasible within 5 years. The case shown here is calculated for replacing LPG where pay back time is still up to 8.2 years. The industrial application is based on a solar system that would require a storage tank and glazed collectors in a case of replacing fuel oil. With the initial cost of 23,000 Baht/m^2, solar systems for commercial and industrial applications need more than 6 years to pay back the investment. In order to reduce the pay back period to less than 5 years, a 50% initial cost reduction is needed, which is higher percentage than the residential application required due to low price of fuel even they are escalated at 10%/year. The potential of future increase of LPG price due to ceasing of government subsidy on the fuel may make the pay back period shorter than the current price. There are financial incentives can make this initial cost reduction possible such as tax privilege, tax incentives, tax credit, subsidy or other policies. Reviews of international policy in success countries and recommendations for Thailand will be illustrated in Chapter 8.

Table 5.9 Pay back periods for the reduction of initial cost

Sectors	**Current**		**Percentage of initial cost reduction**				
	Pay back time	**Initial cost (Baht/m^2)**	**50%**	**40%**	**30%**	**20%**	**10%**
Residential[1]	6.2	29,000	3.5	4.1	**4.7**	5.2	5.7
Commercial[2]	8.2	23,000	**4.9**	5.6	6.3	7	7.6
Industrial[3]	7.7	23,000	**4.5**	5.3	5.9	6.6	7.2

Note
1. Residential solar system replacing electricity
2. Commercial solar system replacing LPG
3. Industrial solar system replacing fuel oil