CHAPTER VI

COST ESTIMATION

For simplicity, the economics of the solar house was divided into two types of expenses. One was the operating costs (costs of fuel oil, electricity and other utilities for operating such equipment as heaters, pumps, etc.). The other was the fixed investment costs (costs of equipment and installation costs, etc.).

The electricity costs for households was calculated based on the announcement of rates by the Metropolitan Power Board which was effective from 1st August 1981 (See Appendix A). TABLE 6.1 summarizes the number of kilowatt-hours consumed by the electric equipment during the 4 summer months of 1979. TABLE 6.2 summarizes the total number of kilowatt-hours consumed by the electric equipment for total 4 months. TABLE 6.3 summarizes the estimated costs of electricity for the 4 months of each case.

TABLE 6.1(a)

Electricity Consumption by Electric Equipment in March 1979

Type of Equipment	Rating (Watt)	Simulation Case					
		Case 1		Case 2		Case 3	
		Operating hours	No.of kWh	Operating hours	No.of kWh	Operating hours	No.of kWh
1. Collector pump	195	237.5	46.31	238.2	46.45	242.4	47.27
2. Absorption chiller pump	195	418.1	81.53	425.5	82.97	400.1	78.02
3. Circulation pump	195	418.1	81.53	425.5	82.97	400.1	78.02
4. Fan coil	280	418.1	117.07	425.5	119.14	400.1	112.03
5. Fan for cooling tower	170	418.1	71.08	425.5	72.34	400.1	68.02
6. Cooling tower pump	240	418.1	100.34	425.5	102.12	400.1	96.02
7. On/off controllers (3 units)	6 (each)	744.0	13.39	744.0	13.39	744.0	13.39
		Total	511.25	Total	519.38	Total	492.77

TABLE 6.1(b)

Electricity Consumption by Electric Equipment in April 1979

Type of Equipment	Rating (Watt)	Simulation Case					
		Case 1		Case 2		Case 3	
		Operating hours	No.of kWh	Operating hours	No.of kWh	Operating hours	No.of kWh
1. Collector pump	195	220.6	43.02	215.8	42.08	220.3	42.96
2. Absorption chiller pump	195	500.5	97.60	450.6	87.87	420.5	82.00
3. Circulation pump	195	500.5	97.60	450.6	87.87	420.5	82.00
4. Fan coil	280	500.5	140.14	450.6	126.17	420.5	117.74
5. Fan for cooling tower	170	500.5	85.09	450.6	76.60	420.5	71.49
6. Cooling tower pump	240	500.5	120.12	450.6	108.14	420.5	100.92
7. On/off controllers (3 units)	6 (each)	720.0	12.96	720.0	12.96	720.0	12.96
		Total	596.52	Total	541.69	Total	510.06

TABLE 6.1(c)

Electricity Consumption by Electric Equipment in May 1979

Type of Equipment	Rating (Watt)	Simulation Case					
		Case 1		Case 2		Case 3	
		Operating hours	No.of kWh	Operating hours	No.of kWh	Operating hours	No.of kWh
1. Collector pump	195	213.7	41.67	209.7	40.89	216.7	42.26
2. Absorption chiller pump	195	452.6	88.26	469.0	91.46	438.2	85.45
3. Circulation pump	195	452.6	88.26	469.0	91.46	438.2	85.45
4. Fan coil	280	452.6	126.73	469.0	131.32	438.2	122.70
5. Fan for cooling tower	170	452.6	76.94	469.0	79.73	438.2	74.49
6. Cooling tower pump	240	452.6	108.62	469.0	112.56	438.2	105.17
7. On/off controllers (3 units)	6 (each)	744.0	13.39	744.0	13.39	744.0	13.39
		Total	543.87	Total	560.80	Total	528.90

TABLE 6.1(d)

Electricity Consumption by Electric Equipment in June 1979

Type of Equipment	Rating (Watt)	Simulation Case					
		Case 1		Case 2		Case 3	
		Operating hours	No.of kWh	Operating hours	No.of kWh	Operating hours	No.of kWh
1. Collector pump	195	167.3	32.62	164.6	32.10	180.0	35.10
2. Absorption chiller pump	195	421.5	82.19	428.7	83.60	415.3	80.98
3. Circulation pump	195	421.5	82.19	428.7	83.60	415.3	80.98
4. Fan coil	280	421.5	118.02	428.7	120.04	415.3	116.28
5. Fan for cooling tower	170	421.5	71.66	428.7	72.88	415.3	70.60
6. Cooling tower pump	240	421.5	101.16	428.7	102.89	415.3	99.67
7. On/off controllers (3 units)	6 (each)	720.0	12.96	720.0	12.96	720.0	12.96
		Total	500.80	Total	508.05	Total	496.58

TABLE 6.2

Total Electricity Consumption by Electric Equipment for 4 months

Type of Equipment	Rating (Watt)	Simulation Case					
		Case 1		Case 2		Case 3	
		Operating hours	No.of kWh	Operating hours	No.of kWh	Operating hours	No.of kWh
1. Collector pump	195	839.1	163.62	828.3	161.52	859.4	167.59
2. Absorption chiller pump	195	1792.7	349.58	1773.8	345.89	1674.1	326.45
3. Circulation pump	195	1792.7	349.58	1773.8	345.89	1674.1	326.45
4. Fan coil	280	1792.7	501.96	1773.8	496.66	1674.1	468.75
5. Fan for cooling tower	170	1792.7	304.76	1773.8	301.55	1674.1	284.60
6. Cooling tower pump	240	1792.7	430.25	1773.8	425.71	1674.1	401.78
7. On/off controllers (3 units)	6 (each)	2928.0	52.70	2928.0	52.70	2928.0	52.70
		Total	2152.45	Total	2129.92	Total	2028.32

The other utility costs are the costs for fuel oil used to operate the heaters. Our simulation results revealed that the domestic hot water heater was not required at all during the summer because the storage tank water temperature had to be kept high to operate the absorption chiller. TABLE 6.4 summarizes the costs of fuel oil required to operate the main heater. It was assumed that the main heater had an average thermal efficiency of 80 %.

TABLE 6.5 lists the total operating costs of the system for each case. The fixed or investment costs for all equipment, including piping and installation are listed in TABLE 6.6.

To determine the economic feasibility of the solar system, we list the operating and investment costs of an equivalent 3-ton electric compression air-conditioner and electric water heating device for comparison in TABLE 6.7-6.8. The compression air-conditioner was assumed to have an average thermodynamic efficiency of 60 % while the electric hot water heater an average efficiency of 90 %.

TABLE 6.3

Electricity Costs of Electric Equipment

Month	Electricity Costs (Baht)		
	Case 1	Case 2	Case 3
1. March	975.68	992.75	834.82
2. April	1154.74	1039.60	973.17
3. May	1044.18	1079.74	1012.75
4. June	953.74	968.96	944.88
Total	4128.34	4081.05	3765.62

TABLE 6.4

Costs of Fuel Oil for the Main Heater

Month	Cost of Fuel Oil (Baht)					
	Case 1		Case 2		Case 3	
	Liters used	Cost	Liters used	Cost	Liters used	Cost
1. March	200.7	1025.36	229.4	1171.98	156.6	800.05
2. April	176.7	902.74	299.1	1528.07	210.6	1075.93
3. May	280.7	1434.07	335.3	1713.01	288.6	1474.43
4. June	385.0	1966.93	417.2	2131.43	362.3	1850.95
Total	1043.1	5329.10	1281.0	6544.49	1018.1	5201.36

TABLE 6.5

Operating Costs of the Solar System

Month	Operating Costs (Baht)		
	Case 1	Case 2	Case 3
1. March	2001.04	2164.73	1634.87
2. April	2057.48	2567.67	2049.11
3. May	2478.25	2792.75	2487.18
4. June	2920.66	3100.39	2795.83
Total	9457.43	10625.54	8966.99

TABLE 6.6

Investment Costs of the Solar System

Type of Equipment	Investment Costs (Baht)		
	Case 1	Case 2	Case 3
1. Flat-plate collector (~ 2000 Baht/m^2)	183360.00 ($91.68\ m^2$)	152800.00 ($76.4\ m^2$)	213920.00 ($106.96\ m^2$)
2. Heat storage tank (Stainless steel) (~ 1400 Baht/m^3)	6753.60 ($4.824\ m^3$)	5600.00 ($4.0\ m^3$)	7896.00 ($5.64\ m^3$)
3. Glass wool 26 cm. insulate heat storage tank (2", 2.973 m^2 ~ 473.6 Baht)	9231.45 ($11.59\ m^2$)	7965.00 ($10\ m^2$)	9924.40 ($12.46\ m^2$)
4. On/off controllers (3 units) (1 unit ~ 14000 Baht)	42000.00	42000.00	42000.00
5. Main heater	30000.00	30000.00	30000.00
6. Hot water fired absorption chiller (3 tons) with Fan coil	55000.00	55000.00	55000.00
7. Cooling tower	10000.00	10000.00	10000.00
8. Pumps and pipings (5 % of all 7 items above)	17317.25	15668.25	18937.02
9. Insulation for the whole house	40000.00	40000.00	40000.00
Total	393662.30	359033.25	427677.42

TABLE 6.7

Operating Costs of the Electric System

Month	Number of kWh	Operating Costs (Baht)
1. March	6705.49	13983.58
2. April	6602.69	13767.70
3. May	6767.22	14113.21
4. June	5659.78	11787.59
Total	25735.18	53652.08

TABLE 6.8

Investment Costs of the Electric System

Electric Appliances	Cost (Baht)
1. Air-conditioner 3 tons	30000
2. Hot water heater 5.5 kW	6520
Total	36520

Next we computed the costs of long term investment as follows:

Electric System

Initial investment cost 36520 Baht

Depreciation period 5 years

Monthly fixed cost (monthly instalments with 18 % annual interest)

$PVIFA^{(27)} = 3.1272$

$$\frac{36520}{3.1272 \times 12} = 973.18 \text{ Baht}$$

Therefore, monthly total cost $= 973.18 + \frac{53652.08}{4}$

$= 973.18 + 13413.02$

$= \underline{14386.20}$ Baht

Solar System

Case 1: Initial investment cost 393662.30 Baht

Depreciation period 10 years[19]

Monthly fixed cost (monthly instalments with 18 % annual interest)

PVIFA = 4.4941

$$\frac{393662.30}{4.4941 \times 12} = 7299.61 \text{ Baht}$$

Monthly total cost $= 7299.61 + \frac{9457.43}{4}$

$= 7299.61 + 2364.36$

$= \underline{9663.97}$ Baht

Case 2: Initial investment cost 359033.25 Baht

Depreciation period 10 years

Monthly fixed cost (monthly instalments with 18 % annual interest)

PVIFA = 4.4941

$$\frac{359033.25}{4.4941 \times 12} = 6657.49 \text{ Baht}$$

Monthly total cost $= 6657.49 + \frac{10625.54}{4}$

$= 6657.49 + 2656.39$

$= \underline{9313.88}$ Baht

Case 3: Initial investment cost 427677.42 Baht

Depreciation period 10 years

Monthly fixed cost (monthly instalments with 18 % annual interest)

PVIFA = 4.4941

$$\frac{427677.42}{4.4941 \times 12} = 7930.35 \text{ Baht}$$

Monthly total cost $= 7930.35 + \frac{8966.99}{4}$

$= 7930.35 + 2241.75$

$= \underline{10172.10}$ Baht

The operating costs of the electric system in TABLE 6.7 were computed from the monthly average cooling loads and the amount of energy required to heat the domestic water from 30°C to 60°C.

We can see from the above calculations that all three cases of the solar system are more economical than the electric system at present. Thus a person who wants to air-condition his whole house 24 hours a day may do well to choose a solar system instead of an electric one. In other words, the higher the air-conditioning loads, the more economical a solar system becomes. On the other hand, if the air-conditioning load is low, or only a small section of the house is to be cooled, or air-conditioning is required only a part of the time, an electric system might be more economical because of its extremely low initial investment costs.

The 18 % annual interest on long-term loans seems in line with the current interest rate. If the interest rate becomes 20 %, the solar system is still found to be economical. In this case, the monthly total cost for the electric system and for Case 1, Case 2 and Case 3 of the solar system turn out to be 14430.65, 10189.09, 9792.81 and 10742.59 Baht/month, respectively.

The depreciation period of the electric system was chosen to be 5 years compared to 10 years for the solar system because the former contains moving mechanical parts which are operated

non-stop all the time.

TABLE 6.9 summarizes the projected yearly savings of the solar system over the conventional electric system. It should be cautioned that the projections were based on only 4-month performance in the summer of 1979, regrettably because of limitation of computer time. Projected Yearly savings in TABLE 6.9 were computed by subtracting the yearly total investment cost of the solar system from that of the electric one year by year. It was also assumed that the cost of the fuel oil used as supplemental energy in the solar system increased at the same rate as that of electricity. Obviously, the steeper the rate of electricity price increases, the more advantageous the solar system becomes. Under these circumstances, Case 3 should give the lowest savings because its fixed cost is largest. By the same reasoning, Case 2 should give the highest savings because its fixed cost is the lowest. The same conclusion can easily be reached by looking at FIGURE 6.1.

TABLE 6.9(a)

Projected Yearly Savings by the Solar System Case 1

Year	Projected Yearly Savings by the Solar System Based on Various Annual Price Increases of Electricity (Baht)					
	CVIF	Annual price increase 0%	CVIF	Annual price increase 4%	CVIF	Annual price increase 8%
1	1	56666.76	1	56666.76	1	56666.76
2	1	56666.76	1.04	61970.12	1.08	67273.47
3	1	56666.76	1.082	67538.64	1.166	78675.69
4	1	56666.76	1.125	73239.75	1.260	91138.58
5	1	56666.76	1.170	79206.03	1.360	104396.97
6	1	44988.60	1.217	73759.31	1.469	107170.45
7	1	44988.60	1.265	80123.34	1.587	122815.36
8	1	44988.60	1.316	86885.12	1.714	139653.51
9	1	44988.60	1.369	93912.07	1.851	157817.51
10	1	44988.60	1.423	101071.59	1.999	177439.93
	Total	508276.80	Total	774372.73	Total	1103048.20

TABLE 6.9(b)

Projected Yearly Savings by the Solar System Case 2

Year	Projected Yearly Savings by the Solar System Based on Various Annual Price Increases of Electricity (Baht)					
	CVIF	Annual price increase 0%	CVIF	Annual price increase 4%	CVIF	Annual price increase 8%
1	1	60867.84	1	60867.84	1	60867.84
2	1	60867.84	1.04	66031.08	1.08	71194.20
3	1	60867.84	1.082	71452.32	1.166	82295.05
4	1	60867.84	1.125	77002.80	1.260	94428.53
5	1	60867.84	1.170	82811.40	1.360	107336.48
6	1	49189.68	1.217	77199.94	1.469	109728.00
7	1	49189.68	1.265	83395.76	1.587	124959.38
8	1	49189.68	1.316	89978.83	1.714	141352.48
9	1	49189.68	1.369	96820.04	1.851	159036.38
10	1	49189.68	1.423	103790.33	1.999	178140.16
	Total	550287.60	Total	809350.33	Total	1129338.50

TABLE 6.9(c)

Projected Yearly Savings by the Solar System Case 3

Year	Projected Yearly Savings by the Solar System Based on Various Annual Price Increases of Electricity (Baht)					
	CVIF	Annual price increase 0%	CVIF	Annual price increase 4%	CVIF	Annual price increase 8%
1	1	50569.20	1	50569.20	1	50569.20
2	1	50569.20	1.04	55931.41	1.08	61293.62
3	1	50569.20	1.082	61561.73	1.166	72822.37
4	1	50569.20	1.125	67326.11	1.260	85423.56
5	1	50569.20	1.170	73358.59	1.360	98829.09
6	1	38891.04	1.217	67981.03	1.469	101762.94
7	1	38891.04	1.265	74415.68	1.587	117581.46
8	1	38891.04	1.316	81252.50	1.714	134606.48
9	1	38891.04	1.369	88357.42	1.851	152972.04
10	1	38891.04	1.423	95596.41	1.999	172812.23
	Total	447301.20	Total	716650.08	Total	1048673.00

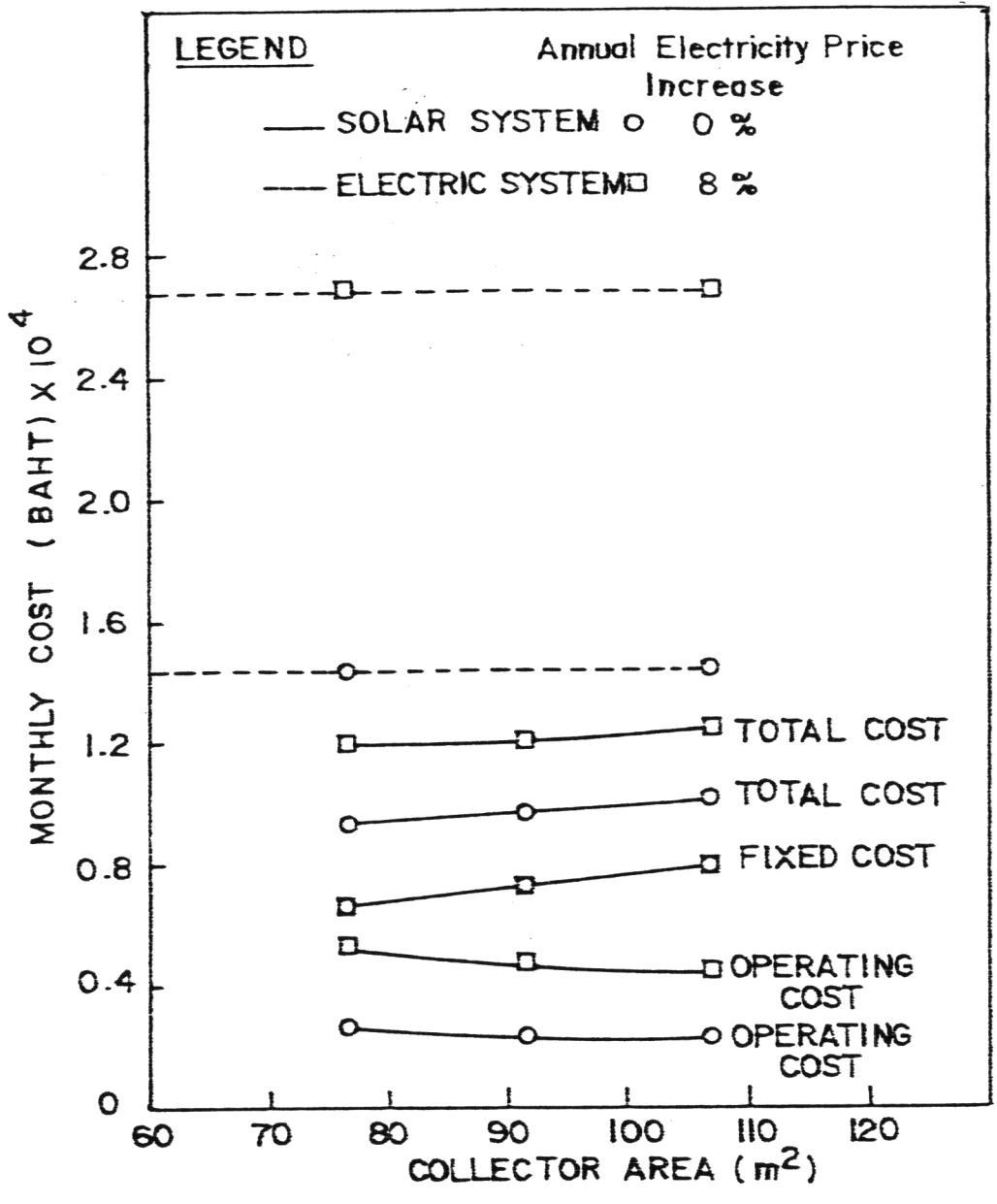

FIGURE 6.1 COMPARISON OF COSTS BETWEEN A SOLAR AND AN ELECTRIC SYSTEM