8.4 Water Pumping with PV system

In Syria, with the rise in standard of living in recent years, water demand for domestic use and for irrigation of agricultural production has increased significantly. As a result, demands for water have increased drastically. In villages on the plains there are old wells, but many of these wells have been dried up. Villagers having no water supply system periodically purchase water and carry by a tank lorry to their houses. As the groundwater quantity is small, if pumping of large quantity of water is continued, water veins will dry up early. Hence the Ministry of Irrigation has a license system for digging of wells. Recently, water treatment facilities have been installed near large cities to recycle water. Under such circumstances, the water pumping with PV system is useful to keep water resources in rural areas, but its economics is big factor. In the following, economics of water pumping with PV system is compared with that of diesel pumping, as a quantity of water is parameter.

(1) Assumptions for economic comparison between PV pumping and diesel pumping

When a diesel engine is used for pumping, water quantity can be changed according to the duration of pump operation when fuel is refilled and operation is kept. In case of PV system, pumping can be made only in the daytime when the sun shines. Hence comparison between them can be made only when the pumping water quantity is limited. The pumping costs of both methods are compared with each other by limiting the quantity of diesel pumping to that of PV system pumping. On the other hand, general-purpose pumps of high reliability for PV use are limited up to about AC 2 kW in capacity. Pumps not higher than this capacity are considered.

(3) Cost comparison with PV pumping

The results of cost calculation using above parameters are shown in Table 8.4-1. Considering that the village population for introducing PV water pumping will be less than 500 and the water demand will be 20～30 liter per person one day, then total water quantity for the village will be 10～15m^3 if it is used for their life. According to the Table, if the application system is up to 40～50m of total head, PV pumping is more economical than diesel under the condition of PV module price of 2005 and inflation rate of 0%. In this table, under inflation rate of 3% the economically possibly area for PV pumping expands to total head of 70m. The water level of most of the wells in Aleppo is up to 50～60m(interview from the Aleppo Water Authority), therefore most wells can be applied with PV pump. According to the mentioned above result, commencement of introduction from 2005 is economically feasible. To introduce PV pump more economically, it is recommended to start with relatively shallow (up to 50m) wells.

Table 8.4-1 Water cost of PV pumping system (unit : US$/m³)

1) PV module life 20years, inflation:0%

Total head (m)	Water Quantity (m^3/day) 5	10	15	20	25	30	35	40
10								
20								
30						0.22(0.05)	0.20(0.05)	0.19(0.04)
40				0.28(0.08)	0.24(0.06)	0.22(0.05)	0.22(0.06)	
50		0.47(0.16)	0.34(0.11)	0.28(0.08)	0.24(0.08)	0.24(0.07)		
60		0.47(0.16)	0.34(0.11)	0.31(0.11)				
70	0.84(0.32)	0.47(0.16)	0.34(0.11)					
80	0.85(0.32)	0.47(0.16)	0.39(0.15)					
90	0.85(0.32)	0.48(0.16)						
100	0.86(0.32)	0.54(0.22)						
110	0.87(0.32)							
120	0.87(0.32)							
130	0.87(0.32)							
140	0.88(0.32)							
150	0.88(0.32)							

2) PV module life 20 years, inflation 3%

Total head (m)	Water Quantity (m^3/day) 5	10	15	20	25	30	35	40
10								
20								
30							0.21(0.06)	0.20(0.05)
40						0.23(0.06)	0.23(0.07)	
50				0.29(0.09)	0.25(0.09)	0.25(0.08)		
60			0.35(0.12)	0.32(0.12)				
70			0.35(0.12)					
80		0.48(0.17)	0.40(0.16)					
90		0.49(0.17)						
100		0.55(0.23)						
110								
120	0.88(0.33)							
130	0.88(0.33)							
140	0.89(0.33)							
150	0.89(0.33)							

3) PV module life 30years, inflation 0%

Total head (m)	Water Quantity (m^3/day) 5	10	15	20	25	30	35	40
10								
20								
30								
40							0.21(0.06)	
50						0.23(0.06)		
60				0.30(0.10)				
70								
80			0.37(0.13)					
90								
100		0.50(0.19)						
110								
120	0.83(0.28)							
130	0.83(0.28)							
140	0.84(0.28)							
150	0.84(0.28)							

result, commencement of introduction from 2005 is economically feasible. To introduce PV pump more economically, it is recommended to start with relatively shallow (up to 50m) wells.

Table 8.4-1 Water cost of PV pumping system (unit : US$/$m^3$)

1) PV module life 20years, inflation:0%

Total head (m)	Water Quantity (m^3/day) 5	10	15	20	25	30	35	40
10	0.69(0.19)	0.39(0.09)	0.29(0.06)	0.24(0.05)	0.21(0.04)	0.19(0.03)	0.18(0.03)	0.17(0.02)
20	0.69(0.19)	0.39(0.09)	0.29(0.06)	0.24(0.05)	0.21(0.04)	0.19(0.03)	0.20(0.05)	0.19(0.04)
30	0.69(0.19)	0.40(0.09)	0.29(0.06)	0.24(0.05)	0.21(0.04)	0.22(0.05)	0.20(0.05)	0.19(0.04)
40	0.70(0.19)	0.46(0.09)	0.34(0.11)	0.28(0.08)	0.24(0.06)	0.22(0.05)	0.22(0.06)	
50	0.70(0.19)	0.47(0.16)	0.34(0.11)	0.28(0.08)	0.24(0.08)	0.21(0.07)		
60	0.71(0.19)	0.47(0.16)	0.34(0.11)	0.31(0.11)				
70	0.84(0.32)	0.47(0.16)	0.34(0.11)					
80	0.85(0.32)	0.47(0.16)	0.39(0.15)					
90	0.85(0.32)	0.48(0.16)						
100	0.86(0.32)	0.54(0.22)						
110	0.87(0.32)							
120	0.87(0.32)							
130	0.87(0.32)							
140	0.88(0.32)							
150	0.88(0.32)							

2) PV module life 20 years, inflation 3%

Total head (m)	Water Quantity (m^3/day) 5	10	15	20	25	30	35	40
10	0.70(0.20)	0.40(0.10)	0.30(0.07)	0.25(0.06)	0.22(0.05)	0.20(0.04)	0.19(0.04)	0.18(0.03)
20	0.70(0.20)	0.40(0.10)	0.30(0.07)	0.25(0.06)	0.22(0.05)	0.20(0.04)	0.21(0.06)	0.20(0.05)
30	0.70(0.20)	0.41(0.10)	0.30(0.07)	0.25(0.06)	0.22(0.05)	0.23(0.06)	0.21(0.06)	0.20(0.05)
40	0.71(0.20)	0.47(0.10)	0.35(0.12)	0.29(0.09)	0.25(0.07)	0.23(0.06)	0.23(0.07)	
50	0.71(0.20)	0.48(0.17)	0.35(0.12)	0.29(0.09)	0.25(0.09)	0.25(0.08)		
60	0.72(0.20)	0.48(0.17)	0.35(0.12)	0.32(0.12)				
70	0.85(0.33)	0.48(0.17)	0.35(0.12)					
80	0.86(0.33)	0.48(0.17)	0.40(0.16)					
90	0.86(0.33)	0.49(0.17)						
100	0.87(0.33)	0.55(0.23)						
110	0.88(0.33)							
120	0.88(0.33)							
130	0.88(0.33)							
140	0.89(0.33)							
150	0.89(0.33)							

3) PV module life 30years, inflation 0%

Total head (m)	Water Quantity (m^3/day) 5	10	15	20	25	30	35	40
10	0.67(0.17)	0.38(0.08)	0.29(0.06)	0.24(0.04)	0.21(0.03)	0.21(0.03)	0.19(0.02)	0.17(0.02)
20	0.67(0.17)	0.38(0.08)	0.29(0.06)	0.24(0.04)	0.21(0.03)	0.21(0.03)	0.19(0.04)	0.18(0.03)
30	0.67(0.17)	0.48(0.08)	0.29(0.06)	0.24(0.04)	0.21(0.03)	0.21(0.05)	0.19(0.04)	0.18(0.03)
40	0.68(0.17)	0.49(0.08)	0.33(0.09)	0.27(0.07)	0.23(0.06)	0.23(0.05)	0.21(0.06)	
50	0.68(0.17)	0.44(0.14)	0.33(0.09)	0.27(0.07)	0.23(0.06)	0.23(0.06)		
60	0.69(0.17)	0.45(0.14)	0.33(0.09)	0.30(0.10)				
70	0.80(0.28)	0.45(0.14)	0.33(0.09)					
80	0.81(0.28)	0.45(0.14)	0.37(0.13)					
90	0.81(0.28)	0.45(0.14)						
100	0.82(0.28)	0.50(0.19)						
110	0.83(0.28)							
120	0.83(0.28)							
130	0.83(0.28)							
140	0.84(0.28)							
150	0.84(0.28)							

8.5 Desalination with PV system

On the premise to keep drinking water in Badia, Hama, the following two specific sites were nominated to consider practically. Normally, about several thousands of Bedouins live around Athrea, Hama County (Site A), and the area is far away from grid lines. Thus the conditions of the area are suitable to introduce salty water desalination system powered by PV. On the other hand, the salinity contents of the well water at Moukhlef, Aleppo County (Site B) is much higher than that of Site A. Site B is selected as a candidate so that we can consider application of the systems to salty water of much higher concentration in future. In this study, the designed electric conductivity of product water was set to be about 500 μ S/cm. The purchasing cost of equipment was assumed and economic feasibility was studied both Reverse Osmosis (hereinafter called RO) and Electro-Dialysis (hereinafter called ED).

8.5.1 Specifications of Desalination Systems

(1) Desalination at Site A

Table 8.5-1 Specifications and costs of desalination system for Site A

	Item	Unit	Cases of R O Membrane Method			Cases of ED Method		
			A1-1	A1-2	A1-3	A2-1	A2-2	A2-3
Specifications	Well Water Feed	m^3/hr	20	10	5	20	10	5
	Desal. Water Prod.	m^3/hr	13.2	7	3.3	14	7	3.5
	Recovery Rate	%	50	50	50	70	70	70
	E.C. of Desal. Water (Designed	μ S/cm	50	50	50	500	500	500
	Electr. Consumption	kWh/m^3	1.89	2.8	3.0	0.85	0.85	0.85
	Max. Elec. Consum'n.	KW	25.7	16.5	9.0	15.8	8.2	4.4
	Well Water Mixed	m^3/hr	3	1.5	0.75	0	0	0
	Product Water	m^3/hr	13	6.5	3.25	14	7	3.5
Initial Cost	Equipment	US$	141,505	85,497	56,693	116,130	99,442	82,754
	Civil Work	US$	76,000	53,200	44,600	76,000	53,200	44,600
	Total	US$	217,505	138,697	101,293	192,130	152,642	127,354
Running Cost	Consumables	US$/m^3	0.05	0.05	0.05	0.03	0.03	0.03
	Spare parts	US$/m^3	0.80	0.81	0.90	0.79	1.06	1.27
	Labor	m^3	0.20	0.04	0.09	0.02	0.04	0.09

(2) Desalination at Site B

It is assumed that a desalination system is to be introduced to Site B of which salinity contents are higher than that of Site A. The desalinated water production quantity of the system is about 10 m^3/hr. Both systems of RO and ED are considered.

The assumptions are shown in Table 8.5-2.

Table 8.5-2 Assumption of desalination system for site B

	Item	Unit	Cases of R O Membrane Method B 1	Cases of ED Method B 2
Specifications	Well Water Feed	m^3/hr	20	13.3
	Desal. Water Prod.	m^3/hr	10	10
	Recovery Rate	%	50	75
	E.C. of Desal. Water (Designed)	μ S/cm	500	500
	Electr. Consumption	kWh/m^3	1.89	2.9
	Max. Elec. Consum'n.	KW		
	Well Water Mixed	m^3/hr	3	0
	Product Water	m^3/hr	11	10
Initial Cost	Equipment	US$	89,452	79,914
	Civil Work	US$	76,000	61,000
	Total	US$	165,452	140,914
Running Cost	Consumables	$US\$/m^3$	0.08	0.05
	Spare parts	$US\$/m^3$	0.80	1.75
	Labor	$US\$/m^3$	0.02	0.03

(3) PV system

In each case, a scale of PV system operating desalination system is planned taking into consideration of on raw water, pumping up, water produced and operation hours of desalination based on typical insolation in November when insolation is decreasing. The construction and work cost of PV system for desalination is assumed on reference to actual data of centralized PV system in Zarzita and desalination system in Kalif. Those assumptions are shown in the Table 8.5-3.

Table 8.5-3 Cost for PV System

	Item	Unit	Cases of RO Membrane Method				Cases of ED Method			
			A1-1	A1-2	A1-3	B1	A2-1	A2-2	A2-3	B2
Equipment Spec.	PV module	KW	48	36	18	48	31	16	8.4	74.4
	Inverter	KW	30	20	10	30.0	20	10	5	40
	Controller	A	200	200	100	200	170	90	50	310
	Battery	kWh	96	72	36	96	72	36	21.6	144
	Pump	kW	2.2	1.5	1.1	2.2	2.2	1.5	1.1	2.2
Installation Cost	PV module	US$	144,000	108,000	54,000	144,000	91,800	48,600	25,200	223,200
	Inverter	US$	15,000	10,000	5,000	15,000	10,000	5,000	2,500	20,000
	Controller	US$	1,000	1,000	500	1,000	850	450	250	2,550
	Battery	US$	4,000	3,000	1,500	4,000	3,000	1,500	900	6,000
	Pump	US$	5,050	4,040	3,670	5,050	5,050	4,040	3,670	4,640
	Installation	US$	11,790	9,489	6,309	11,790	7,881	5,022	4,187	20,432
	Total Cost	US$	180,840	135,529	70,979	180,840	118,581	64,612	36,707	276,822

8.5.2 Evaluation of desalination systems

(1) Desalinated water cost at Site A

Desalinated water cost is discussed based on annual amount of produced water with the scale of desalination system as parameters, for both RO and ED.

a. In the same scale of desalination system on RO and ED, respectively, produced water quantity would be nearly same. The amount of produced water increases due to longer sunshine hours from February to August and gradually decreases from September. During minimum insolation in winter, the amount of produced water becomes minimum, but fortunately living water would be expected from rainfall to be useful.

b. Based on the quantity of water produced in October, which is most difficult to keep drinking water, if necessary water quantity for drinking is about 15 litters per day, how many people could provide for living water is shown in the Table 8.5-5.

Table 8.5-5 No. of people supplied drinking water (October)

Scale / Supply	A1-1	A1-2	A1-3	Remark
No. of people	7,920	3,987	1,862	Supply amount 15l/day/person

Under the above-mentioned conditions, average cost of desalinated water throughout the year is shown in Table 8.5-6. Findings include the following:

a. Greater system capacity, the lower the cost of desalinated water. For instance, when the production rate is about 10 m^3/hr, the unit cost of the desalinated water is US$1.50/$m^3$ for ED, and US$1.72/$m^3$ for RO. ED is about US$0.2/$m^3$ cheaper than RO.

b. As for the cost characteristics of desalination, the water cost of RO tends to decrease with the increase in capacity. On the other hand, the cost of ED is substantially constant.

c. If inflation rate is assumed to be 3%, produced water cost increases about 15%.

d. If life is extended from 20 years to 30 years, the effect on the produced water cost is a decrease by about 10%.

Table 8.5-6 Desalination water cost at Site A

a) RO

Item			A 1 − 1			A 1 − 2			A 1 − 3		
			Capability of producing water 13.2[m³/h] Water 39,546[m³/year]			Capability of producing water 6.5 [m³/h] Water 19,989[m³/year]			Capability of producing water 3.25 [m³/h] Water 9,350 [m³/year]		
Condition	Item	Unit	PV	Desalination	Total	PV	Desali nation	Total	PV	Desali nation	Total
Life: 20 year Inflation rate: 0%	Fixed cost	US$	12,997	19,740	32,737	9,776	12,588	22,364	5,259	9,193	14,452
	Variable	US$	396	34,623	35,019	298	18,129	18,427	159	9,825	9,984
	Annual cost	US$	13,393	54,363	67,756	10,074	30,717	40,791	5,418	19,018	24,436
	Fixed cost	$/m³	0.33	0.50	0.83	0.49	0.63	1.12	0.56	0.98	1.54
	Variable	$/m³	0.01	0.88	0.89	0.01	0.91	0.92	0.02	1.05	1.07
	Cost	$/m³	0.34	1.38	1.72	0.50	1.54	2.04	0.58	2.03	2.61
Life: 20 year Inflation rate: 3%	Fixed cost	US$	13,336	19,740	33,076	10,027	12,588	22,614	5,412	9,193	14,605
	Variable	US$	530	46,334	46,864	399	24,261	24,660	212	13,149	13,361
	Annual cost	US$	14,585	66,074	80,659	10,426	36,849	47,818	5,624	22,342	28,286
	Fixed cost	$/m³	0.34	0.50	0.84	0.50	0.63	1.13	0.58	0.98	1.56
	Variable	$/m³	0.01	1.17	1.18	0.02	1.21	1.23	0.02	1.41	1.43
	Cost	$/m³	0.35	1.67	2.02	0.52	1.84	2.36	0.60	2.39	2.99
Life: 30 year Inflation rate: 0%	Fixed cost	US$	11,346	19,740	31,086	8,528	12,588	21,116	4,613	9,193	13,806
	Variable	US$	396	34,623	35,019	298	18,129	18,427	159	9,825	9,984
	Annual cost	US$	11,742	54,363	66,105	8,826	30,716	39,543	4,772	19,018	23,790
	Fixed cost	$/m³	0.29	0.50	0.79	0.43	0.63	1.06	0.49	0.98	1.47
	Variable	$/m³	0.01	0.88	0.89	0.01	0.91	0.92	0.02	1.05	1.07
	Cost	$/m³	0.30	1.38	1.68	0.44	1.54	1.98	0.51	2.03	2.54

Interest rate 6.5%

b) ED

Item			A 2 − 1			A 2 − 2			A 2 − 3		
			Capability of producing water 14 [m³/h] Water 40,193 [m³/year]			Capability of producing water 7 [m³/h] Water 20,376 [m³/year]			Capability of producing water 3.5 [m³/h] Water 10,584 [m³/year]		
Condition	Item	Unit	PV	Desalination	Total	PV	Desali nation	Total	PV	Desali nation	Total
Life: 20 year Inflation rate: 0%	Fixed cost	US$	8,691	17,437	26,128	4,834	13,853	18,687	2,884	11,558	14,443
	Variable	US$	261	33,956	34,217	144	23,178	23,322	84	14,839	14,923
	Annual cost	US$	8,952	51,393	60,345	4,978	37,031	42,009	2,968	26,397	29,366
	Fixed cost	$/m³	0.22	0.43	0.65	0.24	0.68	0.92	0.27	1.09	1.36
	Variable	$/m³	0.01	0.84	0.85	0.01	1.14	1.15	0.01	1.40	1.41
	Cost	$/m³	0.23	1.27	1.50	0.25	1.82	2.07	0.28	2.49	2.77
Life: 20 year Inflation rate: 3%	Fixed cost	US$	8,958	17,437	26,395	4,993	13,853	18,846	2,996	11,558	14,554
	Variable	US$	349	45,442	45,791	193	31,018	31,211	113	19,859	19,972
	Annual cost	US$	9,828	62,879	72,186	5,496	44,871	50,367	3,109	31,417	34,735
	Fixed cost	$/m³	0.22	0.43	0.65	0.25	0.68	0.93	0.28	1.09	1.37
	Variable	$/m³	0.01	1.13	1.14	0.01	1.52	1.53	0.01	1.88	1.89
	Cost	$/m³	0.23	1.56	1.81	0.26	2.20	2.46	0.29	2.97	3.26
Life: 30 year Inflation rate: 0%	Fixed cost	US$	7,633	17,437	25,070	4,262	13,853	18,115	2,566	11,558	14,124
	Variable	US$	261	33,956	34,217	144	23,178	23,322	84	14,839	14,923
	Annual cost	US$	7,894	34,217	59,287	4,406	37,031	41,437	2,650	26,397	29,047
	Fixed cost	$/m³	0.19	0.43	0.62	0.21	0.68	0.89	0.24	1.09	1.33
	Variable	$/m³	0.01	0.84	0.85	0.01	1.14	1.14	0.01	1.40	1.41
	Cost	$/m³	0.20	1.27	1.47	0.22	1.82	2.03	0.25	2.49	2.74

Interest rate 6.5%

(2) Desalinated water cost at Site B

At Site B, salinity contents are higher than that of Site A. The cost of desalinated water of RO and that of ED are compared with each other. Both systems are of the same capacity.

a. Water desalination capacity of RO system is 10.7m³/hr, and that of ED system is 10.0m³/hr. The quantity of desalinated water by month of ED system is a little lower than that of RO system.

b. As for the number of people who can receive drinking water from these systems, when it is judged from the quantities of desalinated water in October, RO system can supply water to about 6,420 persons and ED system about 6,270 persons, respectively

c. When the salinity contents rises, RO method is more advantageous than ED method in terms of desalinated water cost. When the useful life is 20 years and inflation rate is 0%, the water cost is US$1.79/m³ for RO, and that for ED is US$2.88/m³, respectively; the latter is higher by about 50%.

Table 8.5-7 Desalination water cost at Site B

Item			RO			ED		
			Capability of producing water 10.7 [m³/h] Water 32,056 [m³/year]			Capability of producing water 10 [m³/h] Water 31,551 [m³/year]		
Condition	Item	Unit	PV	Desalination	Total	PV	Desalination	Total
Life: 20 year Inflation rate: 0%	Fixed cost	US$	12,997	15,016	28,012	19,707	12,789	32,496
	Variable	US$	396	28,993	29,389	607	57,854	58,461
	Annual cost	US$	13,392	44,009	57,401	20,314	70,643	90,957
	Fixed cost	$/m³	0.41	0.47	0.88	0.62	0.41	1.03
	Variable	$/m³	0.01	0.90	0.92	0.02	1.83	1.85
	Cost	$/m³	0.42	1.37	1.79	0.64	2.24	2.88
Life: 20 year Inflation rate: 3%	Fixed cost	US$	13,336	15,016	28,352	20,148	12,789	32,937
	Variable	US$	530	38,801	39,331	813	77,424	78,237
	Annual cost	US$	14,586	53,817	67,683	21,982	90,213	112,195
	Fixed cost	$/m³	0.42	0.47	0.89	0.64	0.41	1.05
	Variable	$/m³	0.02	1.21	1.23	0.03	2.45	2.48
	Cost	$/m³	0.44	1.68	2.12	0.67	2.86	3.53
Life: 30 year Inflation rate: 0%	Fixed cost	US$	11,346	15,016	26,361	17,108	12,789	29,897
	Variable	US$	396	28,993	29,389	607	57,845	58,461
	Annual cost	US$	11,741	44,009	55,751	17,715	70,643	88,358
	Fixed cost	$/m³	0.35	0.47	0.82	0.54	0.41	0.95
	Variable	$/m³	0.01	0.90	0.91	0.02	1.83	1.85
	Cost	$/m³	0.36	1.37	1.73	0.56	2.24	2.80

Interest rate : 6.5%

9. Overall Evaluation

In this project, village electrification, water pumping and desalination powered by PV system is introduced and study were made to improve the human life of rural area through installation, management of these systems and development of cottage industry. In here, based on the outcome of this project, the feasibility of PV system etc is evaluated by the aspect of technology, economics, social, management and environment.

9.1 Technical evaluation of the introduced PV system

The centralized PV system and the individual small-scale PV system was started operation in Sep 1997, and the water pumping system in Zarzita was started in Mar 1998. On the other hand, the individual medium-scale PV system and the water pumping / the desalination system in Kalif was started their operation in Aug 1998 as well. The technical evaluation was executed regarding the introduced system based on the analysis of operation data, the situation of maintenance and troubleshooting.

9.1.1 Village electrification by PV system

(1) Centralized PV System

①State of power supply and consumption

After commissioning, noticeable issue was the addition of 100W and 10W incandescent lamps by villagers. When villagers understood the convenience of electricity, an electric appliances of the amusement usage that is radio-cassette, B&W or color TV was purchased. Continuously, the electric appliance to reduce women's daily work, which is washing machine and iron, has increased.

The increasing of appliances is evidenced by a sharp rise in power consumption from approx. 2,600kWh/2months, which was about 70% of the design load (approx. 4,000kWh/2months) in the beginning and to 4,700kWh/2months. Moreover, on Jul to Aug 1999, the consumption was 7,200kWh/2months. However, even in winter season that the insolation is low, the night demand can be covered. Therefore, the initial design is satisfied.

②Battery Capacity

Based on the actual power consumption, the ratio of total consumption is assumed to divide into 20% for daytime and 80% for night. According to this assumption, the battery operation of the centralized system was studied. 20% of depth or less of discharge of power consumption is acceptable for daily cycle services and about seven years life is expected. However, depth of discharge is over 20%, this is slightly deep for daily cycle services. Especially, during two months of Jul to Aug 1999, daily depth of discharge was recorded about 28.6%. Battery life was affected by the condition of battery management. Therefore, the battery characteristics should be understood to sustain the battery life as long as possible.

③Inverter capacity

Capacity of the inverter for the centralized PV system is 35kW, which seems to have a small margin against the current peak load of about 20.5kW. According to SSRC/HIAST's inventory survey of electric appliances in Zarzita, refrigerators, washing machines and other electric rotating machinery are on the rise. These rotary machines ask rush current during startup. Namely, the inverter must have capacity enough to take up these instantaneous peak loads. On the other hand, the inverter installed has capabilities to connect to the commercial grid. Therefore, if the inverter has capacity comparable to the total capacity of PV array, it will be able to send power to the grid system in excess of demand, maximizing the capacity utilization. While the inverter is seemingly given an ample margin at present, it is justifiable considering the future expandability.

(2) Individual PV System

①State of power demand and supply

On Fedre, based on the situation of electric appliances, the number of light, radio-cassette and TV were not increased and the other appliances were not introduced. The villagers of Fedre used their load appropriately. Some requirement to use washing machine is there, but the villagers were satisfied to use lighting, radio and TV for the time being.

On Katoura, radio cassette and B&W TV is slightly increased, but particularly, 18(W) fluorescent lamp that is mainly used for livestock house are sharply increased. Katoura villagers understand a convenience of electricity. It is estimated that the introduction of appliances and the amount of consumption is increased and it is necessary to check carefully.

On Kalif, the system is AC system, however, the electric appliances is not increased like Zarzita. Only 5(W) incandescent is increased. In Kalif, about half of the houses become vacant in the dry season (summer) as people work away from their homes. During their absence, the system continues to charge the batteries without discharge. This is one of reason to accelerate water evaporation from the battery. At present, regarding these vacant houses, the inspection cycle was made short to once a month during the summer season same as the other system and it is correspond that charge circuit is off.

②Notices on system operation

The every individual system was not stopped operation even in winter season. Thus, the scale of system introduced is reasonable. However, these systems will be utilized effectively to pay attention to the following issues.

a. Individual small-scale PV system

In winter, power supply and demand is balanced, but the power generated beyond consumption sometime in the daytime of summer. Therefore, if the small-scale inverter is introduced to operate washing machine etc and the power generated is utilized effectively; it is useful to improve rural area development.

b. Individual medium-scale PV system

From the viewpoint of balance of supply and consumption, the scale of the introduced system was adequate. However, in Kalif, about half of the houses become vacant in the dry season (summer) as people work away from their houses. Thus, if more effective plan, which separates a part of this system and convert to the portable system is studied, the PV system is useful to introduce for Bedouin of Al Badia area.

(3) Situation of technology transfer

Based on check result of system management including maintenance by SSRC/HIAST, the outcome of technology transfer through system designing, installation and trial operation is utilized effectively and the result arrangement and analysis of collected data is smooth. Therefore, in future, when all of system management activity is transferred to the both Authorities, the related Authorities can keep sustainability of installed system under the supervision of SSRC/HIAST.

(4) Future introduction of PV system

In case of a village, which is close to electrified town by grid line, people are well aware of the utility of electricity, and their holdings of electric appliances are rapidly increasing both in variety and quantity and demand is also large. Therefore, in case of these villages, it is difficult to control the demand of the villagers.

On Fedre, which is far from the grid and few of cultural exchange comparatively, the number of electric appliances and demand were not increased through this project. Under these condition, some demand to use washing machine is there, but the basic needs of the villagers were satisfied to use lighting, radio and TV for the time being. In future, it seems unlikely that the electric appliances and power demand increase sharply, though it is necessary to watch carefully.

In Syria, the electrification of rural area has been promoted, and the average electrification rate is exceeded 70%. At present, the villages, which are located in the desert area, and the small-scale village, which is quite far from the grid line, are only remained. In this case, some of these areas have economical advantage for individual PV system. In future, PV system is studied to introduce such as the small-scale un-electrified villages and to satisfy the basic human needs.

9.1.2 PV water pumping/desalination system

(1) System scale

Usually, the scale of PV pumping system is determined by water quantity and total head. Total head is determined by the well to be introduced PV pumping. Water quantity is determined by the one-day water demand per person and the population of the village. Therefore the most important factor for sizing the system is the one-day water demand per person. Generally, minimum one-day water demand per person is considered only 9 liter. But Zarzita, which is near town, will possibly be advanced, thus the water demand is set to be 20 liter per person. At present, people use more water because people do not know the real ability of the system. In near future the demand will be lessened and it will come to the designed value.

②Design method

The important factor for designing is well condition and water demand described above and insolation as well. Insolation of winter is relatively small, but in this season rainwater is available to use, so it will not limit the design condition. The critical point is the end of dry season because the saved rainwater runs short and insolation is getting small. Thus, capability of water pumping is necessary to meet those demands. The insolation of the season is considered to be 5kWh/m^2. Sometimes water level of the well varies according to seasons. Therefore, using the insolation and well condition of this season, scale of system is decided by the manufacturer's designing procedure.

SSRC/HIAST learned to design PV pumping system using these values through this project. It is expected that the design procedure will be transferred gradually to the related organizations such as the Water Authority

③Water distribution method

The water distribution method implemented in this project connecting plastic hose during scheduled time is meaningful and can be used in the future rural water supply. In this project, extra work of monitoring is needed and an operator is selected separately from a contractor. But for normal system, one person should conduct these two jobs. The fee of the water should be determined considering the reward for the work.

(2) Water pumping / Desalination system

①Validity of the technology

Although the power supply by PV system is non-continuous by the condition of insolation, it will not have much adverse effect on the desalination system. However, power supply to the desalination equipment was request to be constant and applied to the emergency case, minimum capacity of battery was installed.

The desalination performance of the system decreased by 3-4% in less than one year after commissioning, though at first the system performed the desalination rate of 99% or more as originally designed. This is attributable to that the equipment was put into complete stop for about two weeks when the first water leak was detected at the activated carbon filter tank, and also after that period, the chemical cleaning of RO membrane was not adequate. As long as appropriate maintenance of the desalination system is conducted, a stable operation should be expected. After establishing operation and maintenance organization, the desalination system is thought to use as long as possible.

③Validity of scale of desalination unit

In the original design of the system, sunshine hours each day was assumed to be about 5.5 hours, and accordingly fresh water production quantity was set to 2.3

m^3/day. However, actual fresh water production quantity was about 20% more. Because, based on the background that the Syria's standard for drinking water quality is less severe than that of Japan, the process of the desalination system was changed in accordance with local request for producing as much fresh water as possible. According to the operation results of the desalination system, the average production quantity of desalinated water was about 1m^3/day in winter and about 4 m^3/day in summer. The quantity of the desalinated water is fluctuated by season, but the fresh water distribution of about six liters per person per day is secured in winter. As for this amount, it is almost minimum quantity for drinking and cooking, thus, the desalination system of larger scale is preferable as long as there is room in budget in order to provide enough fresh water for drinking and cooking use.

④Influence to environment

a. As for desalination system, the desalinated water is produced by separating impurity such as salinity. On the other hand, high salinity condensed water is produced as well. In Kalif system, this condensed water mix with raw well water and use for multi-purpose. Salinity contents of this multi-purpose water is seasonally fluctuated but yearly average is 3,000 to 7,000 μ S/cm. In Kalif, yearly rainfall is about 300mm, therefore, this multi-purpose water is available to use for irrigation, because diluting effect by rainfall is expected. Thus, no salinity contents problem will be happened for soil. However, in case of few rainfall seasons, when this water is considered to use for irrigation, some attention is necessary to keep reasonable salinity contents by controlling mixture ratio with raw water etc.

b. RO membrane is necessary to wash by chemical product. On Kalif system, waste fluid is discharged near facility. This waste fluid is solution of alkaline and acid and no toxic liquid is mixed. Therefore, whenever, waste fluid is neutralized by alkaline and acid, it is no influence to environment. Therefore, on Kalif system, it is discharged to waste water pit and neutralized in soil. However, in case of large desalination system, wastewater mixture tank is necessary.

9.2 Evaluation of system management

The objective of system management is to make proper maintenance of the respective systems of electrification and pumping/desalination so as to maintain their proper functions over their useful lives or more and accomplish the sustainability of these systems. To this end, proper system management should be executed and necessary fees should be collected. To do this, SSRC/HIAST concluded agreements on system management with the Electric Authority and the Water Authority, respectively. After agreement singed, system management for electrification was transferred to the Electric Authority and for water to the Water Authority, respectively. As a result, the Water Authority started fee collection from April 2000. On the other hand, it took much more time for the Electric Authority to consider setting of fees. However, the fee collected was set at January 2001. Now, both Authorities are ready to make full-scale system management.

(1) Management organization

On the systems located in four villages, the Aleppo Electric Authority appointed the person responsible for operation and management of electricity, and the Aleppo Water Authority appointed the person responsible for operation and management of water, respectively. As dedicated organizations, Economy Unit of the Aleppo Electric Authority in Dartazze is responsible for the PV electrification systems introduced in Zarzita, Fedre, Katoura, and Kalif; Economy Unit of the Aleppo Water Authority in Dartazze is responsible for PV water pumping system in Zarzita; and Economy Unit of the Aleppo Water Authority in Sfireh is responsible for the desalination system in Kalif. For the water supply systems, the selected contractors collect water fees.

(2) Engineers Training for the Electric Authority and the Water Authority

After the agreements concerning system management were concluded, both Authorities sent their engineers to SSRC/HIAST. In SSRC/HIAST, they received training with necessary teaching materials. The practical training at the sites of systems is also made with participation of engineers of SSRC/HIAST. After this training, the engineers of the Electric Authority mainly executed operation and maintenance of the electrification systems, and the engineers of the Water Authority mainly executed that of water pumping/desalination system. As the condition of operation and maintenance were checked and has no problems, the supervision of SSRC/HIAST is quite suitable.

(3) Relation between fees set and direct cost of management

1) Setting of electricity fees

On the setting of fees by the Electric Authority, it took much time to consider the following grounds.

a. In the rules of power supply of the Electric Authority, there are no provisions regarding DC supply whereas individual PV systems supply DC power.

b. Power used measures by the electric counter. However, counters have not been installed on the systems except in Zarzita.

c. Fees for electricity by PV system should be set, together with fees for electricity by wind power generation, as a part of renewable energy fees.

For fee of electricity, the unit price of 0.75SP/kWh, which is three times as existing electricity fee was decided by PEDEEE for all of the PV systems introduced. For Zarzita, the reading of the power counter is applied to fix collecting fees. For individual systems in Fedre, Katoura, and Kalif, same unit price as Zarzita and fixed rate service is applied assuming 10 hours per day power generated.

2) Setting of water fees

The Water Authority sets the fees for water pumping and desalination at same level as conventional water fees supplied that is 6.5SP/m^3.

3) Set fees and direct cost of management

RO membranes can be used, with spares, for about 20 years. Maintenance of the other equipment and procurement of almost chemicals are available in Syria. Specially, in Syria, public utility fees are set very low under the government subsidy. Therefore, if this unit price is continued to use, direct cost, which is replacement of battery, controller, and inverter of the introduced system cannot cover. Therefore, it is necessary to adjust this unit price to appropriate price.

(4) Future tasks

①SSRC/HIAST will analyze and examine technical tasks such as secular changes and troubles of the PV systems introduced. SSRC/HIAST will give advices to the both Authorities if a trouble occurs on any of the installed systems.

②As the systems are reliable and their maintenance and operation are easy, both Authorities are planning to give technical training to some residents of the villages so that systems operation can be partly managed by these villagers.

③Katoura is close to the city and grid lines run along the road in front of the village. If the Electric Authority has an electrification plan of Katoura, it is advisable to implement the plan. To use its PV systems effectively, shifting of the systems to another village should be considered.

9.3 Livelihood improving effects

As a specific livelihood improving effect, it was considered the development of a cottage industry through the utilization of surplus electricity in summer by the centralized PV system in Zarzita. Next, on the residents, the effects of village electrification and pumping/desalination with PV systems were evaluated.

9.3.1 Development of cottage industry

Conventional souvenirs of tourist spots in Syria include picture postcards and mosaics. Their variety is not abundant. Production and sales for cloisonné and stone powder products, which are popular in Japan as handicraft, are proposed. Production and sales of cloisonné and stone powder products were un-experienced fields for the residents of Zarzita. Technology transfer of these arts was made to our counterpart. The products were sold as souvenirs at St. Simon Castle and efforts were made to find retail outlets. Zarzita which cottage industry was executed in this project can take advantage of its proximity to St. Simeon Castle where many tourists visit. Therefore, sales of handicrafts for these tourists are considered. Key holder and stone powder product, which are popular in Japan as handicraft is proposed. Trial production and technology transfer of these arts to our counterpart was executed in cooperation with UNDP. Sales of products, which produced by SSRC/HIAST and villagers, got good result. However, from the viewpoint of cottage industry, it is difficult to find suitable spot, which has good condition like Zarzita. Therefore, it is necessary to consider new expansion that is utilized the characteristics of respective areas.

9.3.2 Effects of introduction of PV systems

(1) Changes in lifestyles due to PV system electrification

①Changes in the respective hours of rising, three meals and sleeping

Changes in the respective hours of rising, three meals and sleeping, which give a large framework of daily living, after the installation of the systems were surveyed. Both men and women showed no change in the hour of rising and the hours of meals. However, the hour of sleeping of men was 1.5 hours later than before, and the hour of sleeping of women was 1.2 hours later than before after the installation of the systems. These changes were caused to the radios and TVs and the changes in illuminance of lighting.

②Changes in other times of daily activities

Changes in other times of daily living after the introduction of the systems were surveyed. The largest change was the increases in the time of watching TV by about three hours a day for both men and women. The next largest change was the increase in the time of listening to the radio. These changes indicate that the quantity of information for the villagers increased rapidly.

a. With the increase in the information received, conversations among the family members increased after the introduction of the systems.

b. As lighting of rooms got brighter, the time of reading and study of children increased.

(2) Survey of other effects

A list of expectations related to the introduction of the systems was prepared and asked the residents to evaluate the state of realization of each expectation with ratings of high, intermediate and low. In parallel with this evaluation of the degree of satisfaction with the use of the system by the resident and the state of use of various appliances was investigated. The results are summarized in the following table.

Table 9.3-1 State of realization of expectations

System introduced	Expected effects	Degree of realization(1
PV electricity (Zarzita,Fedre,Katoura,Kalif)	Improvements of living environment, improvements of sanitary conditions (from lamp to fluorescent lamp)	Medium (2
	Installation of street lighting / improved safety at night	High
	Improved safety and convenience inside the house	High
	Communication within a family and among families / increased inflow of external information	High
	Increased time of education / improved rate of literacy and ratio of students who go on to schools of higher grade	Low(3
	Use of electric appliances / lightened labor of women (increased free time, increased time spent with children)	Medium ~ low (4
Water supply system (Zarzita, Kalif)	Improved sanitary environment for residents (supply of water for living)	Medium
	Improved productivity of agriculture and stock farming (increased yield, number of stock, etc.)	Low
	Increased variety of food (cooking) (Increased products of kitchen garden)	Low
	Reduced labor for women and children (Reduced work of drawing water)	Medium
	Saving of money for purchasing water (Reduced expenditure by residents)	High

(1 :Degree of realization: High : 90~80 % of residents indicated satisfaction; Medium : 79 ~50 % of residents indicated satisfaction; Low : 49 % or under of residents indicated satisfaction.

(2 :Energy for lighting has been switched to electricity. Fuels for heating and cooking are conventional kerosene, gas oil, wood and animal excretion.

(3 :It takes time before effects of the system appear in the form of improved rate of literacy and increased ratio of students who go on to schools of higher grade.

(4 :Degree of realization differs between villages in which AC 220 V can be used and villages in which only DC 12 V can be used.

9.4 Economic Analysis of PV Systems

Economics was analyzed by comparing the cost of kerosene lamp and battery-powered TV, which is widely practiced in un-electrified villages in Syria, and the cost of introduction of 60W individual PV system as an alternative to the former.

a. Cost required for kerosene lamp and battery-powered TV is very expensive in comparison with the electricity fees. The living environment of the residents in un-electrified villages is worse and they are forced to bear a greater burden in comparison with the city dwellers and the villagers who live near cities and use electricity of the Electric Authority.

b. If PV system is used as an alternative, thanks to the recent decrease in prices of PV system components, the cost of PV system, which is bases on the prices estimated for 2005, is one fourth of the cost of kerosene lamp and battery-powered TV and PV system is much stable.

Accordingly, introduction of PV systems is a very important issue for the Electric Authority.

9.4.1 Proposal of planning materials of use of PV systems

The target year to start a promotion of introduction of PV systems in Syria was set at 2005 and the cost of power generated and the cost of water were calculated. The economics of various PV systems was compared with that of alternatives.

(1) Village electrification with PV system

As for the village electrification with PV system, the costs of

①Individual PV systems — 5 cases of capacities
②Mini-centralized PV systems — 3 cases of capacities

were compared with costs of electrification by the grid extension and diesel power generation. Moreover, in the cases of mini-centralized systems, the pumping water cost by utilizing a surplus power was examined.

(2) Water pumping with PV system

Head and quantity were used as parameters, and water cost of PV pumping and that of diesel pumping were compared. The advantageous area of PV water pumping was clarified.

(3) Desalination with PV system

To secure drinking water at Badia in the southeast of Hama, and at another point, the water production costs of water pumping and desalination by RO method or ED method with PV system were examined.

As a result, the following can be recommended as fields for use of PV system in Syria:

①Electrification of un-electrified villages

- When the distance from the existing grid lines to the village is 5 km or over, if the number of households is about 40, PV system electrification is more economical. Electrification with grid lines can be more economical than that with PV system only when the village size is large and the power consumptions of the respective households are large.
- When about nine houses are adjacent to each other in the village, if the mini-centralized PV system is introduced, the residents can use conventional electric appliances. Moreover, the surplus power may be used, for example, for pumping of drinking water.
- PV system meets for the electrification of houses of Bedouins who live in Badia. If PV system is partly modified to a portable system, it can be used during their nomadic herding. In the case of grid extension, as they leave the village during the nomadic period of summer, the installed systems are not used.

②Pumping of drinking and other purposes water

- For example, when the head is 60 m and the quantity is 20 m^3/day, PV water pumping is more economical than diesel pumping. PV water pumping is almost maintenance-free whereas diesel pumping requires labor for replenishing oil, startup and shutdown, and periodical maintenance.
- PV water pumping makes no excessive pumping, it is effective in conserving the underground veins.
- If PV water pumping and drip irrigation are combined, agriculture can be practiced even in rural areas in summer. This leads to enhanced productivity of farmers.

③Desalination

Under the present conditions, the water production cost is high and drinking water cannot be supplied economically. However, for example, in the case of RO method, all components and chemicals, except the RO membrane, can be procured in Syria. Hence if efforts are made to prototype and improve a desalination system of Syrian design, it can be an economical system that is suited to brackish water of Syria. When this is realized, it will have many applicable areas.

9.5 Future tasks concerning the introduced systems

Three years have passed since the start of operation of village electrification systems and pumping/desalination systems in the four villages. With the course of time, due to changes in social environment and experiences of the use of such systems, changes can be observed in the views of the residents. On the basis of the actual records of the study, the following tasks, with focus on the systems operation in future are considered. SSRC/HIAST, the Electric Authority and the Water Authority are requested to make appropriate responses in future.

(1) Tasks related to the village electrification systems

①Problem of complaints from the residents of Katoura

When the project was started, at the time, the residents of Katoura judged that no electrification with grid lines would take in the village in at least ten years to come, and they earnestly requested the introduction of PV systems. They accepted the prior explanation and were satisfied with the systems just after the installation. Recently, however, residents have expressed such complaints even after transfer of systems management to the Electric Authority. They would like to use refrigerators and washing machines. Grid lines run along the road that is 1 km away from the village. Therefore, if the Electric Authority has a plan of electrification of this village, it is electrified by grid lines and considers this PV system to shift in another un-electrified village in rural area. The other option is considered to change this system to grid connection type, together with SSRC/HIAST.

②Problems of rapid increase of new houses in Zarzita

Zarzita was a village with 40 households and 400 persons. More than two years have passed since electrification with 35 kW centralized PV system and the start of supply of drinking water at 8 m^3/day by PV water pumping. During this period, a total of eight new houses were built, and this trend of building new houses seems to develop more in future. The capacity of PV system was planned for the initial number of the houses plus natural increase of demand, and it will be difficult in future to maintain the balance between demand and supply. Therefore, the Electric Authority considers extending grid lines to this village at an appropriate time and connecting this PV system to grid line consulting with SSRC/HIAST. Dispatching the Japanese expert is also taken into account at the same time.

③Effective use of PV systems in Kalif

In summer, many residents of Kalif leave the village to make nomadic herding with their livestock. Hence PV systems are not used while they are away. To promote more effective use of these systems, SSRC/HIAST consults with the Electric Authority and partly modify the system into a portable one so that the system can be used during nomadic herding.

④Improving efficiency of systems management with cooperation of residents

Considering high reliability of PV systems, the Ministry of Electricity has been trying to reduce the costs by conducting some works, such as replenishment of distilled water, with the cooperation of residents. In this case, the Ministry of Electricity to extend range of such cooperation while supervising such works to secure technology and safety.

⑤Adjustment of electric fees of PV system

The electricity fees for PV system are provisional. Therefore, this fee will be reviewed and resetting of fees for renewable energy to ensure efficient management.

(2) Water pumping/desalination with PV system

① Water pumping

- The Water Authority has been giving greatest consideration to the management of the pumping system in Zarzita and it has been appointing one dedicated person. As water fees are set low, even the administrative expenses cannot be covered. Therefore, the Water Authority grasp the properties of the system and consider more efficient management through the cooperation of residents like the case of the Electric Authority.

②Desalination

- As already experienced, once the desalination system is shut down over a long period, if proper measures are not taken, its membrane will deteriorate quickly. Hence it is important to have close contact regarding accidents and other interruption of system operation.
- Acquisition of management technologies of the desalination system

  In view of the rises in the standard of living and increases in population in future, it is a very important task to secure drinking water efficiently. To prepare for the future, it is very important to acquire desalination technology while constantly keeping the sustainability of the demonstration systems. To this end, the operation and maintenance manuals should be followed strictly to accomplish the initial objective of the demonstration systems.

(3) Miscellaneous

In Zarzita, surplus electricity by the centralized PV system in summer has been utilized to produce cloisonné and stone powder products. These products are sold as souvenirs to foreign tourists at St. Simon castle near Zarzita. At present there are several kinds of products. The business, however, cannot be continued without successively developing and marketing new attractive products. Therefore, development of new products in cooperation with the department of arts of the University of Aleppo is necessary.

10. Recommendations on the use of PV systems to the government of Syria and Organizations Concerned

The PV system is a part of the use of renewable energy sources and is an effective means for diversifying them. Hence the advanced industrial countries have been positively promoting the introduction of PV systems and wind power generation to tackle the environmental problems and reduce the consumption of fossil fuels. Under such circumstances, it is quite a timely event that the government of Syria and the government of Japan have jointly conducted a demonstrative study of the use of various PV systems in four un-electrified villages in Syria. In the following, with regard to matters to be considered for using PV systems in Syria that are a part of the results of this study, the recommendations was made to the government of Syria and the organizations concerned regarding expansion of PV systems in Syria.

10.1 Matters to be considered in the Use of PV Systems in Syria

In this project, village electrification and pumping/desalination by PV systems were introduced and managed. On the basis of the findings of this study, regarding the expansion of the electrification and pumping/desalination in the future, the following matters are considered to promote smoothly.

(1) Village electrification with PV systems

①Careful explanation to residents at the time of the installation of PV systems

Residents tend to think that electricity from PV systems is similar to grid lines. After PV systems installed, residents tend to complain that they cannot use refrigerators or washing machines because there is a large difference in the available power. It is therefore important to fully explain and convince the residents that rational usage is needed according to the installed capacity of the systems.

②Appropriate sites for electrification with PV systems

To consider the introduction of PV systems, economic comparison with the alternative method of grid extension and diesel generation was carried out, and an appropriate PV system and site to meet the village form was studied.

a. Small-sized villages distant from grid lines

If a village near grid lines is electrified with PV systems, the merits of the extension of grid lines cannot be obtained and the residents will not be satisfied due to the differences in usage of electrical appliances between the two methods. Firstly, electrification plans of the Electric Authority should be evaluated, and small-sized villages that are remote from the grid lines be considered appropriate candidate sites. For example, when the distance from the grid to the village is 5 km or more, if the number of customers is about 40 and their power demands are small, electrification by a PV system is economical. If a mini-centralized PV system is introduced, surplus electricity may also be expected to use, for example, pumping drinking water.

b. Electrification of houses of Bedouins living in Badia

The population of the Syrian Badia is about 600,000, and houses of the Bedouins are scattered all over Badia. It is very efficient to electrify these houses with PV systems rather than grid extensions. If PV systems are modified to be portable, they can use these systems during nomadic herding.

③Consideration of demands after electrification with PV systems

On the electrification of villages with PV systems, the capacity of the PV system is determined according to the assumed demands. Natural increases in demand are considered in this assumption. However, when a mini-centralized PV system is installed, new houses may be constructed. It is necessary to consider in advance the expansion of facilities, grid extensions, etc. in order to cope with such increases in demand.

④Promotion of introduction of PV systems by revising power supply regulations of the Electric Authority

At the time of the system management transfer of electrification with PV systems from the SSRC/HIAST to the Electric Authority, it was determined that due to the power supply regulations of the Electric Authority they could not manage systems such as individual PV systems which supply DC power and have no meters. It is therefore necessary to modify regulations without delay so that PV systems as well as other forms of renewable energy generation systems can be managed smoothly.

⑤Early setting of renewable energy fees

The initial intent was to set the electricity fees for systems management as part of the consideration of renewable energy fees at PEDEEE. However, recently, the fee for electricity was set to three times of the lowest rate price of the conventional fee by PEDEEE. This fee is a tentative rate. Except for the capital costs, even the operation cost of PV systems could not be covered. It is therefore necessary to set and introduce renewable energy fees without delay so as to ensure smooth system management. This is also applicable to the case of supply with grid lines. Demands for electricity are estimated to grow by about 10 % per year in the future. It is necessary to consider measures for avoiding potentially tight financial conditions.

(2) Water pumping/desalination with PV systems

①Effective use of water resources by PV systems.

Water demand in Syria has been increasing rapidly together with improvement of the standard of living. Since groundwater is salty in some areas, it is not easy to secure drinking water for un-electrified villages. On the other hand, there are many places where water is diesel-pumped for irrigation. In the case of diesel pumping, in many cases, the diesel pumps are not operated properly. Thus the quantity control of pumping water is quite difficult to achieve. As a result, excessive water pumping destroys groundwater veins and wells must be bored deeper and deeper.

②Adjustment of water fee

The water fees for pumping/desalination in the two villages have been set to be the same current water fees of the Water Authority. The operation costs of the systems cannot be covered because the water fee is set too low. Therefore, it is very important to adjust the water fees for these systems. Moreover, residents who purchase drinking water pay high costs for transportation and that this differential is great.

③Acceleration of development of desalination technology

The Water Authority has a keen interest in desalination and hopes to desalinate unused, brackish well water within its service areas. The estimated cost of desalination for the year 2005 is still high so the introduction of desalination is yet difficult. However, all of the components and chemicals for desalination, except reverse osmosis membranes, can be procured in Syria. It is an important task for Syria to reduce their costs by developing a desalination system on an experimental basis and to improve it. Further promotion of the development of desalination technologies in SSRC and the Authorities concerned is required.

(3) Maintenance management with participation of residents

The Electric Authority and the Water Authority evaluated high reliability in the electrification and pumping/desalination with PV systems. In using PV systems in the future, the Water Authority is expected to establish a system like the one used by the Electric Authority wherein the maintenance management can be done in cooperation with the residents so as to reduce their maintenance management costs.

(4) Promotion of technical development and cost reduction

For the expansion of PV systems cost reduction is important. Technical development of PV modules and charge controllers and technology improvement in battery production is executed by the mutual cooperation of the public and private sectors in Syria. It is necessary to reduce the total costs of PV systems by shifting to domestic production. Moreover, improvement of technical levels is important by continuing collection of advanced technology information. On the other hand, at the present time it is necessary to import the main materials. Therefore the consideration of the institutional aspects such as import taxes for PV system materials and the simplification of customs clearances are necessary in order to promote material import.

10.2 Potential Areas for Application of PV Systems

As for the method of use of PV systems, desirable areas for the supply of electricity with PV systems was examined by setting plural desirable capacities for both individual and mini-centralized PV systems and comparing their generating costs with that of electrification through grid extension and of electrification through diesel power generation. As for water pumping with PV systems, the head and the quantity were used as parameters, and the water cost was compared with that of diesel pumping. As a result, the economical area where pumping with PV systems were clarified. Finally, as for desalination, two specific sites were selected and the desalination cost of the RO method and that of ED method were analyzed. On the basis of these findings, the potential areas for application of PV systems were identified as follows:

①Electrification (the Ministry of Electricity)

The Ministry of Electricity has been measuring the electrification rates by using the administrative unit (village) as a unit. In 1998, of 12,121 units, 8,751 units have been electrified and the electrification rate was 72 %. The regions containing many un-electrified units were Aleppo (electrification rate = 53%, number of un-electrified units = 1,448), Homs (59%, 412), Hassake (65%, 850) and Raqqa (66%, 433). A total of 3,370 units are left un-electrified in the country. Electrification of such a unit with PV systems is more economical when the village size is smaller and more distant from the grid lines.

②Pumping of drinking water (the Ministry of Housing and Utilities)

For example, the Aleppo Water Authority has many unused wells within its service area. Of such wells, freshwater wells close to un-electrified villages such as the well near Zarzita (classified as unused because the quantity is 10 m^3/hr or under) are candidates. New wells should be included within the scope of candidates by considering the characteristics of PV systems.

③Appropriate sites for pumping of drinking water for livestock and drip irrigation (the Ministry of Agriculture)

a. As for the pumping of drinking water for livestock, brackish water from wells near farmhouses and in extensive grazing lands are within the scope. Because individual farmers are involved, the Ministry of Agriculture should conclude an agreement before implementation. A potential area within the scope is Hassake in the east of Syria.

b. As for drip irrigation, at first pumping should be made on an experimental basis in order to obtain water for high value added crops. Then the fields of application should be extended. Candidate areas are ones where the groundwater level is relatively shallow and the water quantity is high.

④Desalination (the Ministry of Housing and Utilities)

Around the Badia area south east of Syria it is very important to keep water for livelihood, because the underground water is salty. However, at present since the desalination costs are so high an emphasis should be placed on the survey of the technical development conditions of the RO method, ED method and the evaporation method using solar thermal, as well as on technical development such as prototyping and improvement. It is requested to reduce desalination costs based on those technical developments. On the other hand, candidate sites are investigated and the data collected is arranged. Extra care should be taken in the stage of future introduction.

10.3 Recommendation to the government of Syria and the organization concerned

In April 2000, as a result of a proposal made by the Prime-Minister, the Higher Committee for Energy was established. This Committee responds to tasks such as the World Energy Conference and agreed to set up a national center of energy research. In view of such conditions, the timeframe was estimated to be around 2005 from the viewpoints of the accumulation of experience in operation of the demonstration systems in the future and of increased understanding of PV systems on the organization concerned. Regarding renewable energy including PV systems, the following recommendation was made. The Committee will consider this proposal and will promote the development of renewable energy sources as national projects.

10.3.1 Roles of the government of Syria

Development of power sources requires a long time and a huge investment in plants and equipment. Hence, to diversify the energy sources in the future, Syria has been promoting demonstrative studies of the use of renewable energy sources such as wind power generation and PV systems. Since the development of such energy sources does not require a large sum of investment at one time, it is essential to establish a policy without delay and promote its development. As the use of renewable energy sources relates the various Ministries, it is hoped that a new organization will be established to unitarily develop and manage renewable energy systems. To this end, it is necessary for the government to enact a bill on promotion of the expansion of new energy sources without delay and implement national projects. The outline of the bill is as follows:

(1) Setting the target for development of renewable energy sources

It is necessary to develop the country's comprehensive energy demand and supply plan including renewable energy and to set rational targets for the development of renewable energy sources in that plan. This renewable energy includes PV systems, wind power generation, solar thermal heaters, etc. The Higher Committee for Energy can execute such considerations and efficiently make decisions.

(2) Establishment of advisory organizations for considering targets

To assist the government in effectively setting targets, the subcommittees of the Higher Committee for Energy may be asked to consider the following:

- Comprehensive energy demand and supply plan

- Renewable energy development plan
- Technical development plan.

(3) An organization for implementation

Once the development targets are set, the Renewable Energy Development Organization (hereinafter called REDO) that unitarily develops and operates renewable energy sources will be established. However, it is important to introduce renewable energy systems efficiently without any duplication of the activities of the Higher Committee for Energy.

[REDO]

The REDO executes the following four items:

① Introduction of specific development plans for PV systems, wind power generation, solar thermal heaters, etc, commissioning of such plans and their evaluation.

The government determines the specific targets for development of renewable energy sources and related technologies every year. The organization considers plans that are desired by the public establishment (the Electric Authority → village electrification plans with mini-centralized systems, etc.; the Water Authority → plans for the pumping/desalination of villages; the Ministry of Agriculture → irrigation plan of an area), and effectively executes such plans within the framework of targets.

②Establishment of plans for implementing the development of related technologies (efficiency improvement, increase in domestic production rates), commissioning of such plans, evaluation, and application

The organization sets technical development tasks related to renewable energy and promotes such technical developments efficiently by nominating or publicly inviting some organizations (for example, candidates including SSRC/HIAST, Universities, the Electric Authority, the Water Authority, organizations of the Ministry of Agriculture and private sector screened and selected organizations are commissioned to do the tasks), then evaluates the results. Effective technologies are introduced and used.

③Enlightenment and introduction of renewable energy system

Regarding the promotion of the use of renewable energy systems such as PV systems, wind power generation, and solar thermal heaters, extensive publicity activities and education are carried out by the governmental organizations and the local authorities etc based on the project outcome which includes environmental issues as well as elements of rural development. Through these activities, the information regarding the introduction of renewable energy systems is collected and together with information from the local authorities and the governmental organizations is combined and considered in order to make plans for introduction.

④Mutual cooperation among the organizations concerned

Regarding the introduction of renewable energy systems, it is necessary to cooperate not only among the organizations concerned but also with the local authority for promotion. This expansion of renewable energy system includes both aspects. One is the technical aspect such as research and development and operations and maintenance. The other one is the software aspect such as systems management and the collection of fees. On the other hand, for future expansions, an engineer who can carry out operations and maintenance and a planner who can study introduction plans should be trained and located not only in the organization concerned but also at the local authority. Therefore, in order to execute various activities smoothly and efficiently by the organization concerned, REDO arranges and assists them in making the plans and educating capable people.

(4) Budgetary procedure

- Funds needed by REDO are collected as special taxes. For example, a renewable energy tax is collected together with an electricity tax or a petroleum tax. The yield of the renewable energy tax is used exclusively for projects related to renewable energy so as to promote such projects continuously.
- If foreign funds are desired, Japanese loans, etc will be taken into account for use.

Efforts of promoting the introduction of PV systems through the above-mentioned measures should advance the day when PV systems, which are making rapid technical progresses, will be competitive on a commercial basis.

10.3.2 Roles of the respective Ministries and the organization concerned

The respective Ministries have electrical engineers and can fully manage the installation and operation of PV systems. On the other hand, in many cases, the local authority contacts the rural villages directly and collects information. Here, cooperation between the Ministries concerned and REDO is taken into account and the roles of each organization are described toward the future introduction.

(1) Roles of the Ministry of Electricity

The Ministry of Electricity should regard electrification with PV systems as a supplementary technology for reducing investment rather than a technology that competes with electrification through grid extension. The Ministry considers electrification of candidate un-electrified villages with plural mini-centralized systems and selects electrification plans of villages where economic results of electrification are greater than the investment for grid line. The plans are implemented in the following manner:

①Collection of information on PV system plans

The Ministry of Electricity asks the Electric Authority of the respective areas to identify in cooperation with the local authority un-electrified villages for which grid extension cannot be expected for the time being. The Electric Authority quantitatively analyzes and consider to what extent economic results of the installation of PV systems are greater than those of grid extensions. Then the Authorities submit plans to the Ministry. The Ministry analyzes and summarizes the results.

②Establishment and submission of plans

On the basis of the PV electrification plans of the respective Electric Authorities, the Ministry of Electricity considers effective ways of introduction of PV system all over the country, and submits plans of the Ministry itself to REDO.

③Implementation of plans

Based on the results of the screening of the plans by REDO, the Ministry of Electricity implements and operates the PV systems in the selected villages through the Electric Authorities concerned.

④Other items

1) Based on the plans of REDO, a practical education plan is drawn up with the assistance of SSRC/HIAST. An engineer, who carries out maintenance and operations and a planner who executes planning and systems management are educated and located in the Ministry, the Electric Authority and the Local Authority.

2) The Ministry implements the following through the respective Electric Authorities:

a. Education and training of electric work contractors

In view of the advancement of PV systems in the future, the Ministry provides electric work contractors of necessary areas with education and training on the installation and operations of PV systems.

b. Support to private customers who install individual PV systems

When private customers install an individual PV system, in response to a customer's request, the Ministry will help them find a contractor or will execute the installation work. To ensure safety, the Ministry executes inspection of the in-house wiring.

c. Responses to changes in situation

PV system will be installed in place where grid is unexpected, and the PV system will present higher priority method to provide power to these places and villages. However, after installation, if situations will be changed to grid power supply, the Ministry will consider to connect PV systems with the grid or to move the systems to another un-electrified village for utilizing effectively.

(2) Roles of the Ministry of Housing and Utilities

The respective Water Authorities under the control of the Ministry of Housing and Utilities bore many wells to secure drinking water. Of these wells, low quantity wells are left unused. For example, the well in Zarzita is not used, because the water quantity is 10 m^3/hr or less.

①Collection of information on plans of pumping with PV systems

The Ministry asks the respective Water Authorities in cooperation with the local authority to collect information on site surveys and plans (draft) for the use of existing freshwater wells of small water quantity in un-electrified villages where pumping with PV systems is expected to be useful for the residents of the villages. The Ministry analyzes and evaluates the information collected.

②Development and submission of plans ~ implementation of plans

The procedure is similar to that of the Ministry of Electricity.

③Other items

a. According to the plan of REDO, a practical education plan is drawn up in assistance with SSRC/HIAST. The engineer, who carries out maintenance and operations and the planner who executes planning and systems management are educated and located in the Ministry, the Water Authority and the Local Authority.

b. The Aleppo Water Authority has a keen interest in the pumping and desalination of groundwater (salty). For such organizations, we believe it is certainly effective for the assurance of drinking water in the future to seek funds for survey, research and development of desalination from REDO and to conduct a joint research program with SSRC/HIAST.

(3) Roles of the Ministry of Agriculture

The people related to the Ministry of Agriculture whom we have contacted have a deep interest in the use of PV systems and hope to utilize them in order to enhance the livelihood of the residents of the agricultural villages. Here, some examples are proposed by limiting the use of PV systems in the field of agriculture.

① Collection of information on plans for pumping with PV systems and drip irrigation

The Ministry of Agriculture asks the respective agricultural offices in cooperation with the local authority to collect such information. The Ministry analyzes and evaluates the information and then compiles plans that are most desirable to the Ministry. The important factors in screening are farms that can pump water with PV systems, types of crops, and their production. If the Ministry cannot directly implement the plans, the Ministry commissions the implementation of such plans.

②Submission of plans ~ implementation of plans

The procedure is similar to that of the Ministry of Electricity.

③Other items

According to the plan of REDO, practical education plans are drawn up with the assistance of SSRC/HIAST. An engineer who carries out maintenance and operations and a planner who executes planning and systems management are educated and located in the Ministry, the local office of the Ministry like as Jabal Al Hoss office and the Local Authority.

(4) Roles of SSRC/HIAST

As SSRC/HIAST have roles of conducting technical developments for national enterprises and responding to their technical tasks, SSRC/HIAST is capable of positively tackling various techniques of PV systems. Specific roles will be explained in the National Projects of Renewable Energy" that will be prepared in the future. For the time being, it seems to be necessary for SSRC/HIAST to tackle the following tasks:

①Collection of international technical information

As for PV systems technology, positive efforts are in progress in advanced industrial countries to reduce prices of cells through improvements in cell efficiency and thin film process and to mass-produce cells. It is therefore necessary to monitor the price trends and inform the respective organizations concerned of such developments in order to consider such information in their activities.

②Promotion of domestic production of PV systems components

SSRC/HIAST promote technical development for

- Controllers
- Inverters
- Improvement of batteries
- Improvements in efficiency and quality of the laminator process for PV module manufacturing

so as to efficiently produce them domestically while cooperating continuously with public and private sectors and universities.

③Standardization of PV systems

SSRC/HIAST promotes standardization, for example the structure of PV arrays, which are optimal to Syria, so as to reduce the costs.

④ Technical development for increasing the domestic production ratios of desalination systems

SSRC/HIAST jointly promotes technical development of desalination systems with the Water Authorities, etc. so as to increase the domestic production ratios and in turn reduce the costs.

⑤Other items

SSRC/HIAST assists to draw up the comprehensive education plans for REDO. SSRC/HIAST conducts and assists to make a practical plan for the Ministry concerned as well. Moreover, the execution of the actual training is supported and periodical training and technical improvements are planned and executed at the same time.

(5) Roles of the Local Authority

①Collection and arrangement of information

Regarding the present situation of water supply, the demand of power and water, the number and scale of un-electrified villages and the electrification plans by grid extensions at the areas managed by the Local Authority concerned, information is collected and analyzed. Finally, a database is built for future introduction.

②Planning for introduction plans

Using the collected data of villages, the type and scale of PV systems and water pumping systems is studied with the assistance of the local office of the Electric Authority and the Water Authority. Based on the results, an introduction plan is drawn up and submitted to the organization concerned. At this time, if social development factors are estimated by introducing PV systems like the cottage industry in this project, it is also taken into account.

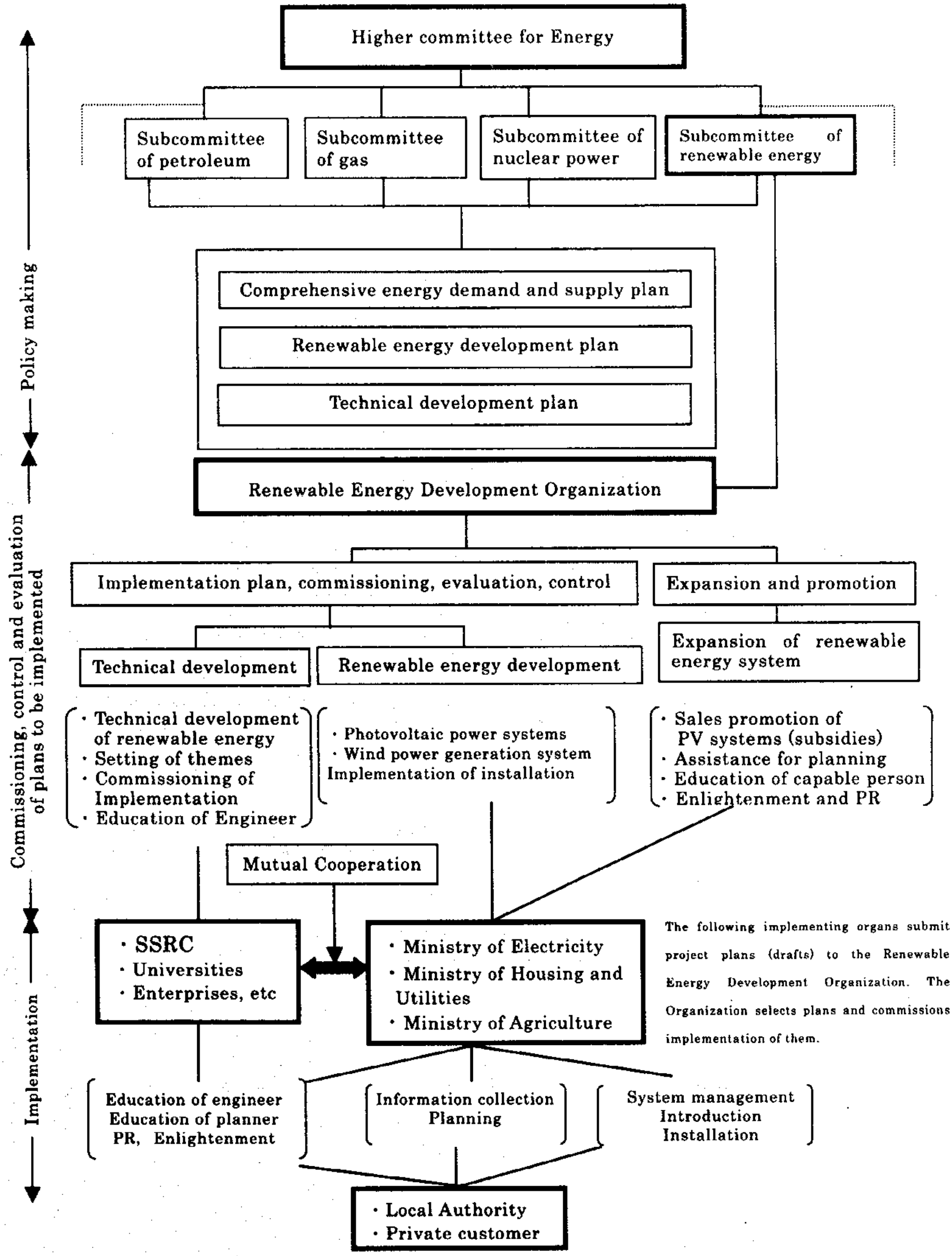
③Assistance for systems management

The activity of systems management, which is installation, maintenance and fees collection by the local office of the Electric Authority and the Water Authority is assisted by the Local Authority from the technical and software aspects.

④Other items

To carry out assistance of systems management and planning for introduction plans, a capable person is educated with the cooperation of the Ministry concerned and SSRC/HIAST.

System for Expansion and Promotion of Renewable Energy (Proposal)



Note) Special taxes are used for budgets of implementation of respective plans.

JICA