JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

SCINTIFEC STUDIES AND RESEARCH CENTER (SSRC)
THE SYRIAN ARAB REPUBLIC

THE STUDY FOR THE INTRODUCTION OF INTEGRATED PHOTOVOLTAIC SYSTEM INTO THE SYRIAN ARAB REPUBLIC

FINAL REPORT (Summary)

MARCH 2001

SHIKOKU RESEARCH INSTITUTE, INC.
THE INSTITUTE OF ENERGY ECONOMICS,JAPAN

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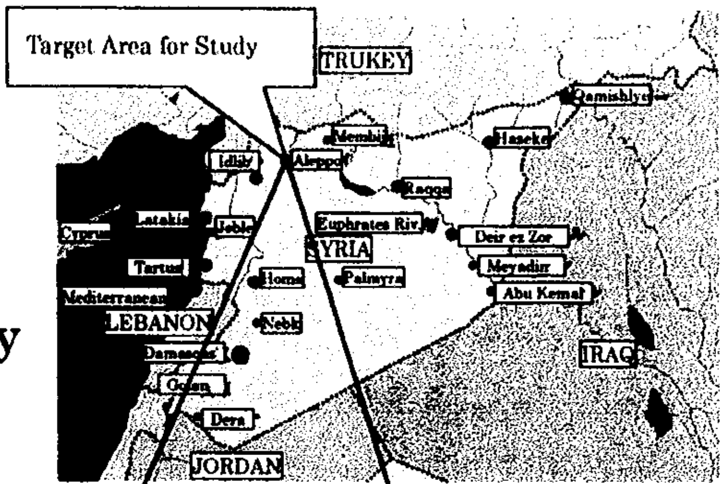
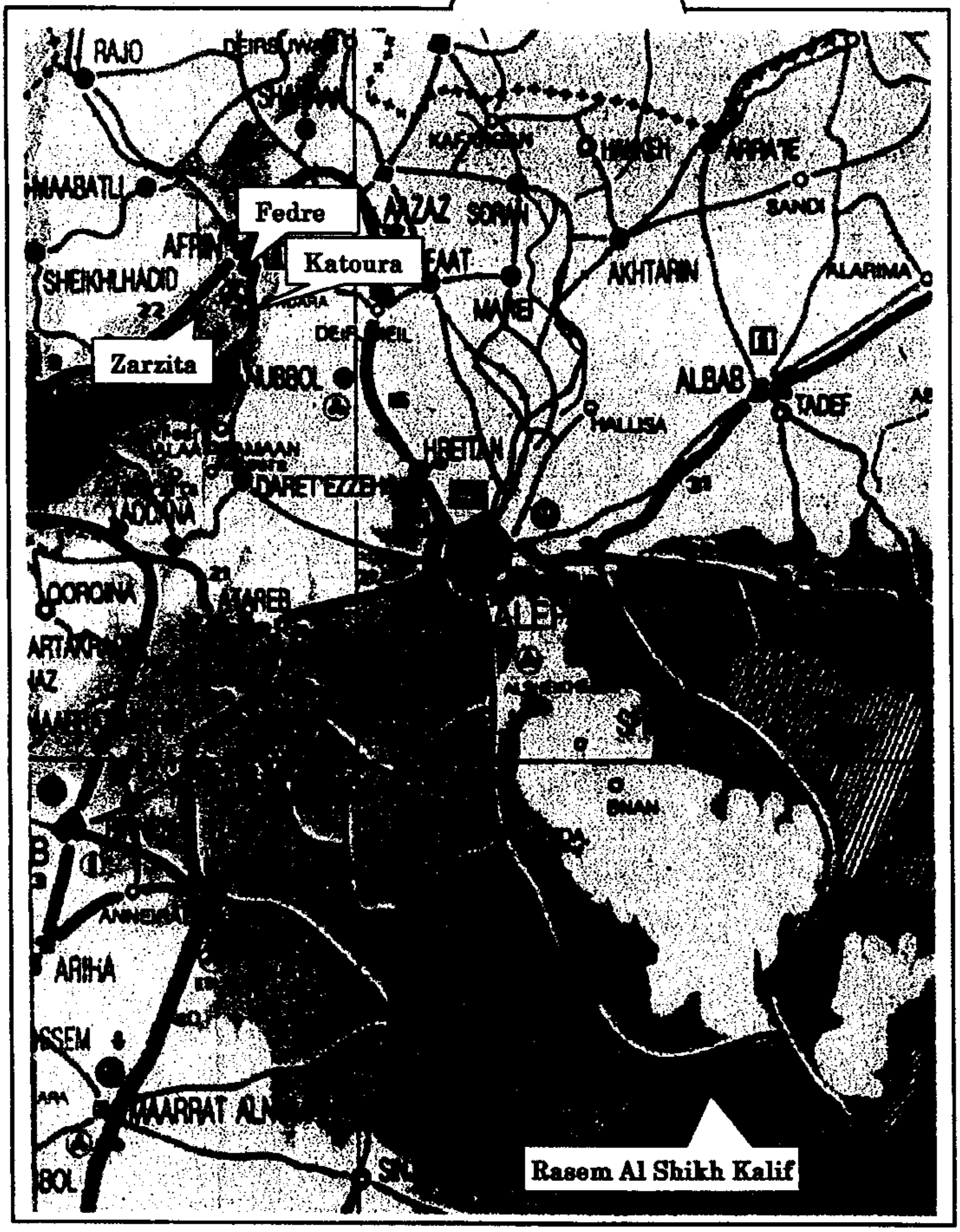
ABBREVIATION

AC	Alternating current
Ah	Ampere hour
CRF	1/capital recovery factor
DC	Direct current
ED	Electro-Dialysis
GDP	Gross domestic product
HIAST	Higher Institute of Applied Science and Technology
Hz	Hertz
IEA	International Energy Agency
PEDEEE	Public Establishment for Distribution & Exploitation of Electrical Energy
PV	Photovoltaic
REDO	the Renewable Energy Development Organization
RO	Reverse Osmosis
SSRC	Scientific Studies and Research Center
SP	Syria Pound
UNDP	United Nations Development Program
S/W	Scope of Work

Target Area for Study





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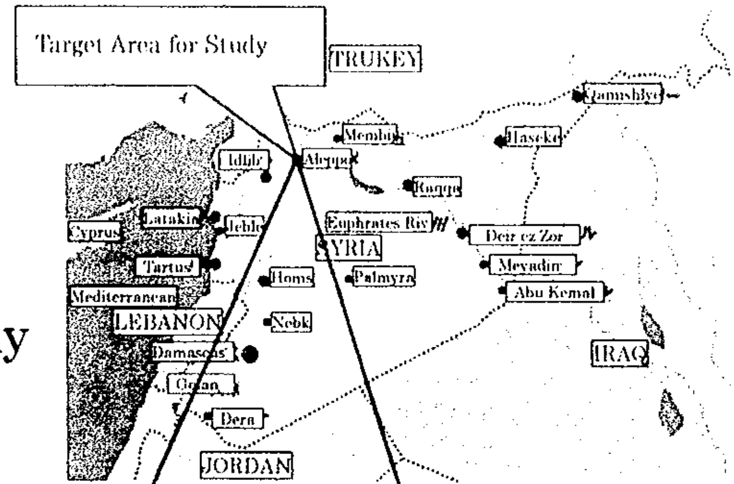
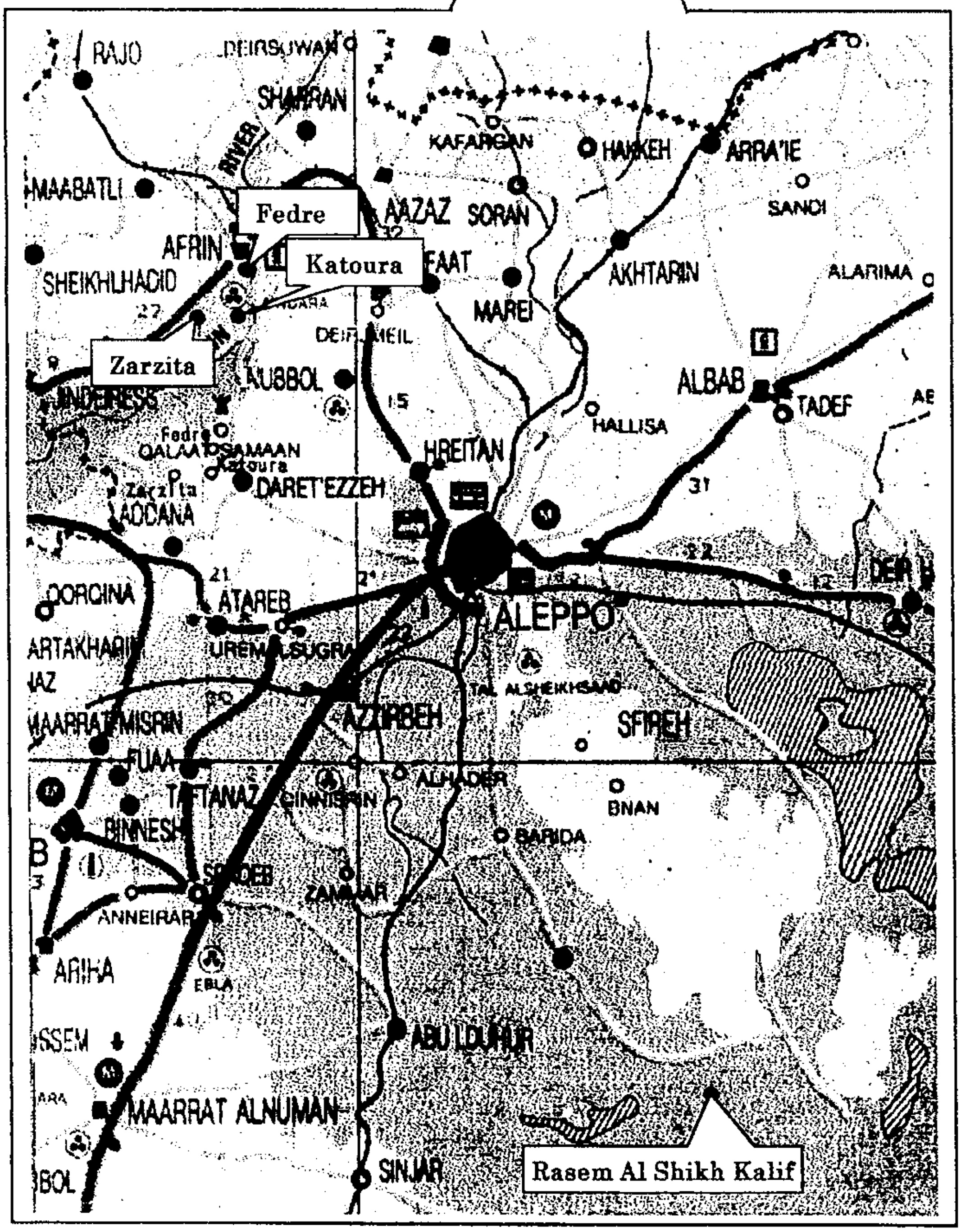




1. Outline of Study

Recently, the concern for environmental issues has been rising in the world such as global warming and breaking of ozone barrier by exhausting carbon dioxide (CO^2) and Flon. In the background of such situation, photovoltaic system (herein referred to as PV system) for utilizing clean and renewable energy was highlighted to contribute very much against the global warming prevention. Not only Japan and the other developed countries but also the developing country in Southeast Asia and the Middle East nations began to accelerate the promotion of PV systems.

1.1 Background of the study

The Syrian Arab Republic (hereinafter called Syria) has vast arid and semiarid regions, including the Syrian Desert, mainly in its southeast. There are about 12,000 villages in these regions and many remote areas in Syria. Of these villages, about 4,000 villages have not been electrified yet to receive the benefit of electricity. Moreover, nearly 3,000 villages are not supplied with water. Most of such villages are small-sized villages located far away from transmission and distribution lines and wells. As for supply of electricity, from the viewpoint of economy, one cannot expect installation of a transmission line or distribution line that requires a large investment. As for supply of water, it is not economically feasible to install a water service installation that requires a large initial investment.

Under such circumstances, on the basis of these findings, the government of Japan held conference with the Scientific Studies and Research Center (SSRC) of Syria and made field surveys. Then the government of Japan and the government of Syria reached full agreement and concluded a Scope of Work on "The Study for the introduction of integrated photovoltaic system into the Syrian Arab Republic" on June 24, 1995. In December 1995, the study team for "The Study for the introduction of integrated photovoltaic system into the Syrian Arab Republic" was sent to Syria.

1.2 Objectives of the study

The village electrification, water pumping and brackish water desalination with PV system was introduced in areas around Aleppo, Syria. The objective of this study was to improve the livelihood of the people in the remote areas through installation, operation and management of these facilities and development of a cottage industry. Through this study, it is intended to verify the feasibility of PV systems in terms of technology, economy, finance, society, organization, management and environment. It is also intended to establish measures for improvement of livelihood of the people of semi-arid and un-electrified areas through the use of PV systems that can be effective and applicable in enhancement of livelihood. Furthermore, it is intended to make technology transfer to the Syrian counterpart during the study. Cooperation is made with UNDP to assist development of a cottage industry and technology improvement of the counterpart.

1.3 Progress of the Study

In this study, surveys were made in Syria and Japan in the period of six years from November 1995 to March 2001. At the completion of the project, Final Report was submitted. The outline of progress is described below.

- In 1996, arrangements were made for engineering of the facilities to be introduced and procurement of equipment and materials. In July 1996, meteorological observation systems were introduced to Zarzita and SSRC building. Also, the battery performance evaluation system was introduced to the laboratory of SSRC.

- From May to August 1997, the centralized PV system in Zarzita and the individual small-scale systems in Fedre and Katoura were installed, and testing and trial operation were conducted. Continuous operation of these systems was started in September to supply electricity in the respective villages. Taking this opportunity of the commencement of continuous operation, a workshop was held in Aleppo University. Moreover, with the commencement of the centralized PV system operation, trial manufacture of cloisonné wares started as a part of development of a cottage industry. In March 1998, the water pumping system in Zarzita was installed, and trial operation of the system was made. After the final inspection, continuous operation of the system was started to supply water.

- From July to August 1998, the individual medium-scale systems and the water pumping/desalination system in Kalif were installed and trial operations of these systems were made. Then continuous operations were started. Surveys of the respective villages into which the facilities were introduced in 1997 were conducted to find any changes in the life style of the residents after the introduction and their attitudes to electricity. As for the development of a cottage industry in Zarzita, with technical assistance given by the experts of UNDP, full-scale production of cloisonné wares was started, and trial sale of the products was started in St. Simeon's Castle near Zarzita.

- In the field survey from June to September 1999, a follow-up survey of the conditions of the operation, management, maintenance and inspection of the introduced facilities was made, and consultation concerning system management was made. As a result, it was confirmed that the Ministry of Electricity is in charge of village electrification systems, the Water Authority of Aleppo is in charge of the pumping system in Zarzita and the pumping/desalination system in Kalif. Finally, the agreement with the Water Authority of Aleppo was signed up in August, and the agreement with the Electric Authority of Aleppo in November. After this agreement signed, system management activity was shifted to the both Authorities. Based on the outcome of technical and economical aspect, advantage and available area for PV system was discussed and organization and institution aspect was studied for the future expansion.

- Comprehensive system management including fee collection did not started in fifth project year (1999). Therefore, to make comprehensive evaluation including system management and recommendation including policy and organizational aspect toward future introduction, project period extended one year. During this year, fee collection for the Water Authority started in April 2000 and the Electric Authority set up temporary fee for PV electricity in January 2001. As a result, comprehensive system management by the both Authorities was started.

  In February 2001, seminar was held at SSRC Damascus and the outcome of this project was reported to the Ministries and the organizations concerned of Syria.

The introduced facility for each village is described below.

(1) Village electrification system

Zarzita

Type of system	Quantity	Outline of main equipment
Centralized PV system (Start : Sep 1997)	For 40 houses	PV array 35kW Inverter 40kVA Battery 336kWh Distribution facility In-house wiring facility, Pre-fabricated house etc

Fedre

Type of system	No. of system	Outline of one system
Individual DC system (DC200W) (Start : Sep 1997)	15	PV array 200W Controller 300W Battery 2,400Wh(1 x 12V-200Ah) In-house wiring facility etc

Katoura

Type of system	No. of system	Outline of one system
Individual DC system (DC300W) (Start : Sep 1997)	24	PV array 300W Controller 300W Battery 2,400Wh(1 x 12V-200Ah) In-house wiring facility etc

Kalif

Type of system	No. of system	Outline of one system
Individual AC system (AC500W) (Start : Aug 1998)	17	PV array 530W Controller 500W Inverter 500W Battery 7,200Wh(6 x 12V-100Ah) In-house wiring facility etc

(2) Water pumping / Desalination system

Zarzita Water pumping system

Type of system	No. of system	Outline of main equipment
Water pumping system (Start : Mar 1998)	1	PV array 6kW Submergible Pump 2 x 0.55kW Transfer Pump 1 x 0.55kW Water reservoir tank x 2 Water transfer line etc

Kalif Water pumping / Desalination system

Type of system	No. of system	Outline of main equipment
Water pumping system (Start : Aug 1998)	1	PV array 1.9kW Inverter 1.5kW Submergible pump etc
Desalination system (Start : Aug 1998)	1	PV array 8.6kW Controller for Desalination system Inverter 10kW Battery 24kWh(20 x 12V-100Ah) Desalination unit Raw water tank Desalinated water tank Pre-fabricated house etc

2 . Outline of Syria

Syria is located in the north of the Arabian Peninsula, stretching from 32° to 37° North Latitude and is a country of socialist republicanism and its total area is 185,180km² approx. or about one half of the area of Japan. According to the statistical data published in 1998, the total population is about 17,500,000 people, and the population of its capital, Damascus, is about 2,800,000 people. The Arabs count for 90% or more of the total population of Syria. Climate of Syria varies from the Mediterranean climate of west to arid desert climate of east. Here, the conditions of the Syrian Arab Republic are outlined, including the conditions of the economy and the electrification.

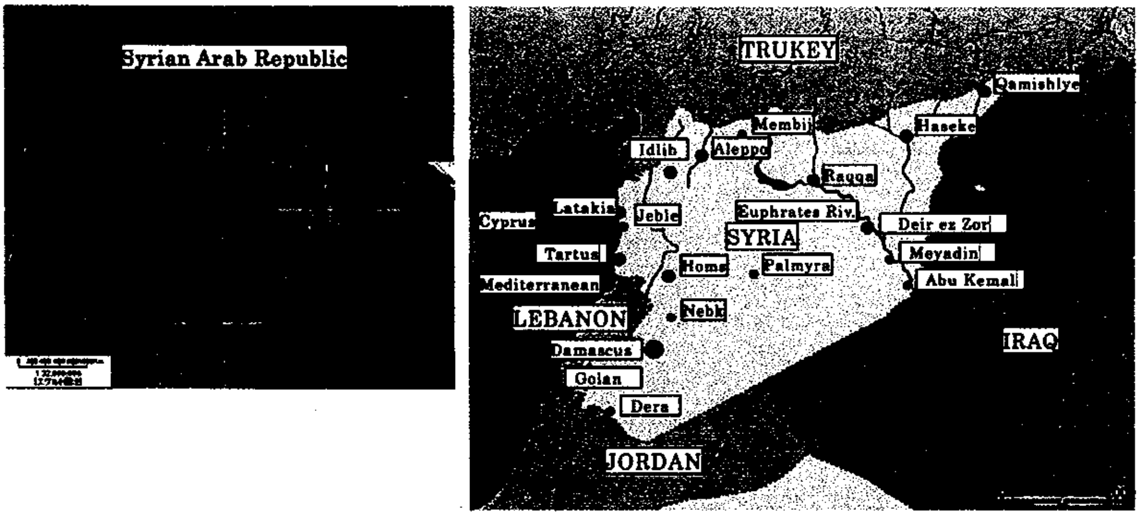
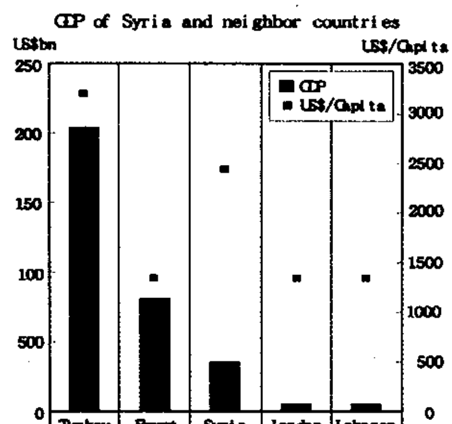


Fig.2.1-1 Map of Syria

2.1 Industries and economy

According to the statistical data of 1997, in terms of GDPs of Syria and its neighbor countries, GDP of Syria is about one half of that of Egypt. GDP per capita of Syria is second to that of Turkey.

As for the industrial structure of Syria, in terms of GDP share by sector, the agricultural sector accounts for 26 %, the mining and manufacturing sector accounts for 24%, and the wholesale and retail sector accounts for 20%.



	Turkey	Egypt	Syria	Jordan	Lebanon
Population (Million)	63.8	60.3	14.9	4.4	4.1
Area (10^3 km²)	775	1001	185	98	10

Source: IEA STATISTICS(1996-1997)

Fig.2.1-2 GDPs of Syria and Neighboring Countries

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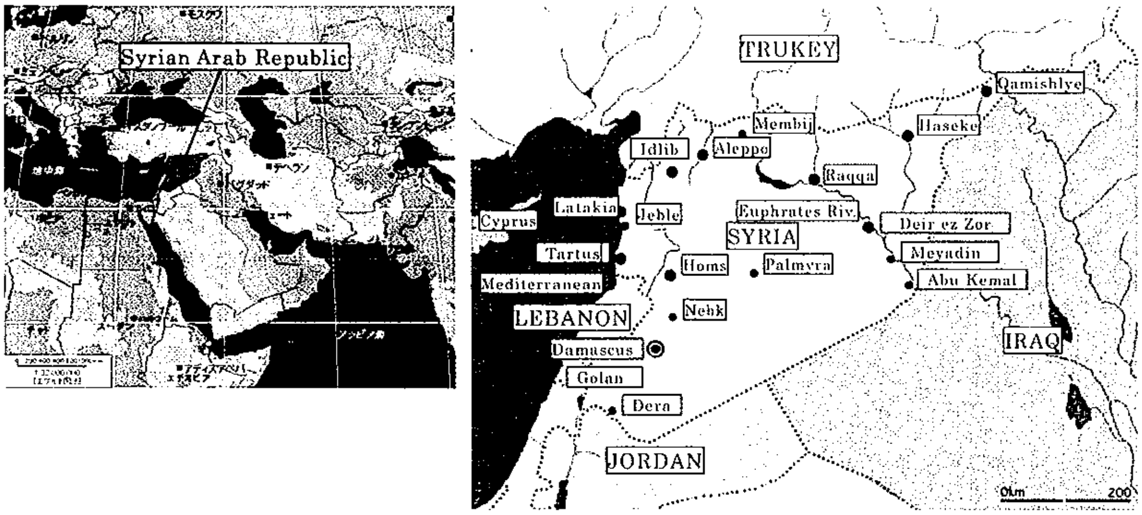

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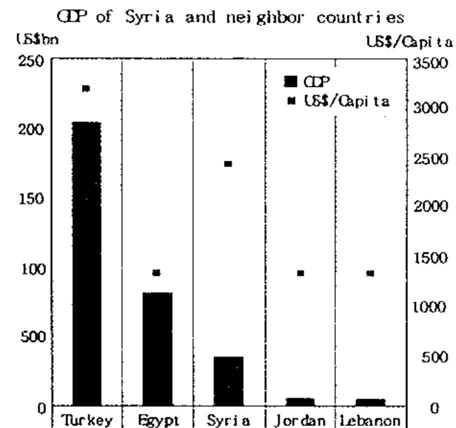

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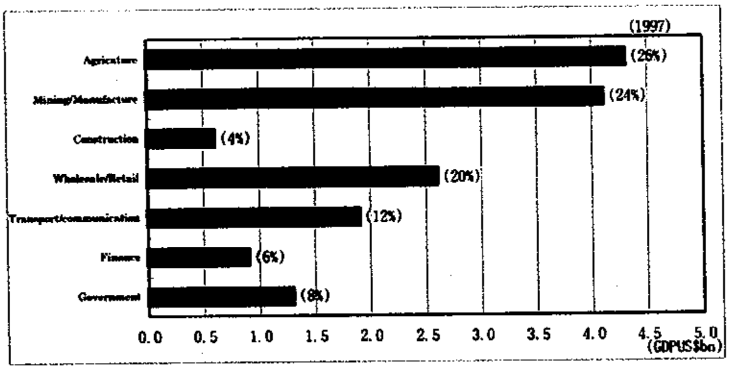
Fig.2.1-2 GDPs of Syria and Neighboring Countries

Major agricultural products include wheat, barley, sugar beet, cotton and citrus fruits. The stock farming produces butter and cheese. As for the production in the industrial fields, main products are those of the textile and leather industries, followed by metal products, foods processing products, and chemical products. Of the industrial productions, in the important sectors such as food, drinks, chemical products and textile, productions of the public establishment account for large shares. In other sectors, the productions of the private enterprises account for large shares. In terms of investment by the sector, which is important in predicting the future directions of the industries, nonmetal mining is followed by food processing and inland transportation.

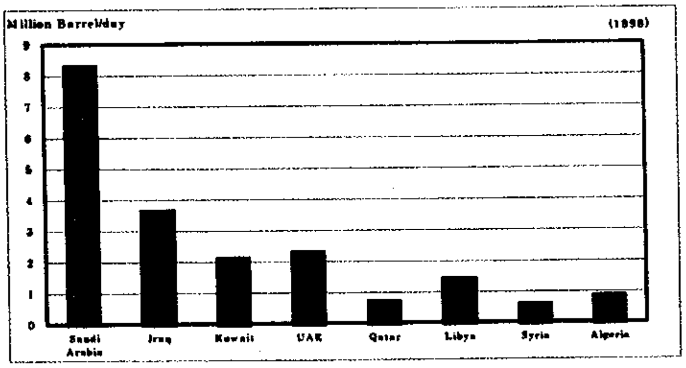


Source : STATISTICAL ABSTRACT (1999)
(SYRIAN ARAB REPUBLIC Office of the Prime Minister
Central Bureau of Statistics)

Fig.2.1-3 GDP of Syria by Sector

2.2 Situation of energy

Crude oil production of Syria is relatively small among the Middle East countries. Produced crude oil is mainly exported. Supply of energy for domestic use in Syria is mainly dependent on the natural gas that is produced in Syria. It is desirable to develop new oil fields by exploring underground resources in future.



Source : OIL & GAS JOURNAL (March 8, 1999)
(1998 Hughes Christensen Company)

Fig.2.2-1 Crude Oil Productions of the Middle East Countries

2.3 Situation of water

Except the western coastal area, almost Syrian land belongs to the dryness climate, and about 3/4 of the country is the arid area, called Badia. The coastal area has a rainfall of 500-1,000mm and farming can be done fully, but rainfall decrease drastically to the eastern area beyond mountains. Area for rainfall of 500mm or more is the western side of the line of Aleppo-Hama-Homs-Damascus. East of this area except for northern part become Badia area. Since most of the rainfall of this area, which is less than 200mm, evaporates soon after it rains, it is difficult to utilize. The Euphrates River is indeed a big water source but the usage of the river water is strongly limited because it is an international river. With the rise in the standard of living, the water consumption is increasing rapidly. In Damascus, Hama, Aleppo, etc., water-treating plants have been constructed to recycle the treated water in agriculture.

On the other hand, groundwater is brackish that salinity contents are about 10 % of the seawater. Thus the groundwater is not fit for drinking. However, it is used as drinking water for the livestock. Freshwater veins also exist among such brackish water veins. Water is a precious resource and it is essential to secure stable supply of water in future. Estimation of water demand is shown in the following table.

Water demands for industrial and domestic uses ($10^3 m^3$)

1992		2000		2025	
Domestic	Industrial	Domestic	Industrial	Domestic	Industrial
761,000	237,804	1,277,500	480,906	282,366	1,292,835

Source : Summary about the situation of Water Resource in Syria
(Eng. Barakot Hadid Deputy Minister of Irrigation)

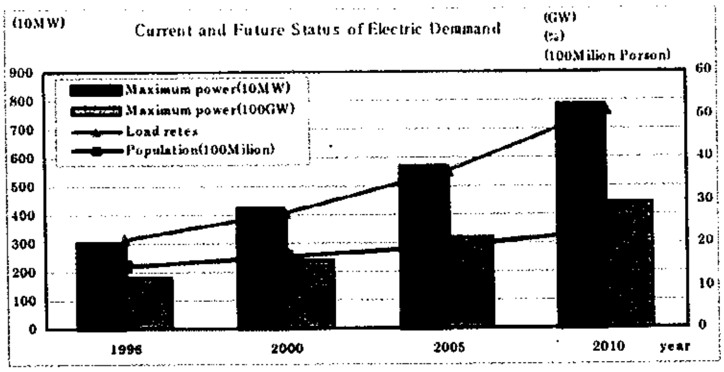
Water demands for irrigation (Unit: $M.m^3$)

1992	2000	2025
10,998	15,367	19,429

Source : Summary about the situation of Water Resource in Syria
(Eng. Barakot Hadid Deputy Minister of Irrigation)

2.4 Situation of power and the state of electrification

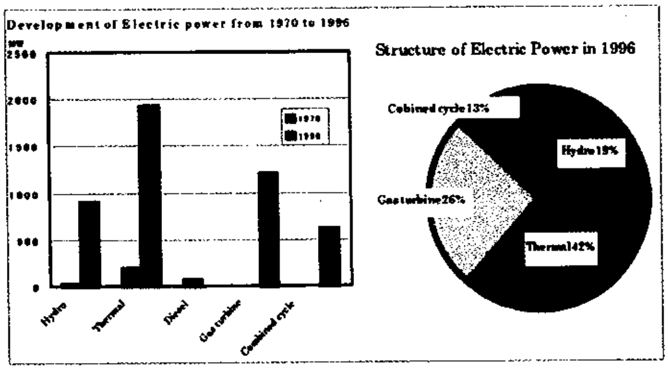
The present condition and future forecast of power demand in Syria are shown in Fig.2.4-1. With the rapid increase in population, the maximum power peak will increase from the present 3 million kW to about 8 million kW in 2010. This is due to the modernization of cities and the improvements in living through expansion of electricity. The annual load factor will be improved from the present 20% to 50%.



Source : Electric Power demand & Runol Electrification in Syria
(Eng. Suhyan Allow : Assistant Minister Electricity)

Fig.2.4-1 Present state and future forecast of Demand

This would require a large investment in electric power development and expansion of transportation facilities. Examination of the past progress of electric power development reveals the changes in power supply. About twenty years ago, the major sources of supply were thermal power plants in the suburbs of large cities, diesel plants and hydropower plants. In recent years, efficiencies have been improved significantly using latest technologies, such as combined cycle power generation, high temperature gas turbine, and new thermal power plants.

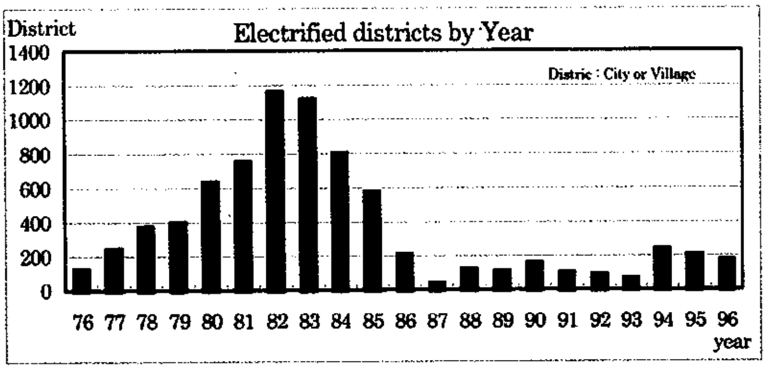


Source: Electric Power demand & Runol Electrification in Syria
(Eng. Suhvan Allow : Assistant Minister Electricitv)

Fig.2.4-2 Transition of power source development from 1970 to 1996

Introduction of new technologies will be continued to secure stable supply of electricity. To meet such supply capabilities, efforts have been made to develop transportation facilities such as 400kV transmission lines in Syria. Moreover, Syria aims to achieve international connection of power systems with those of Egypt, Jordan, Iraq and Lebanon by 2000. Syria also has a plan to connect its power systems with the grid of Europe. Much hope is placed on stable supply of electricity through power pool in future.

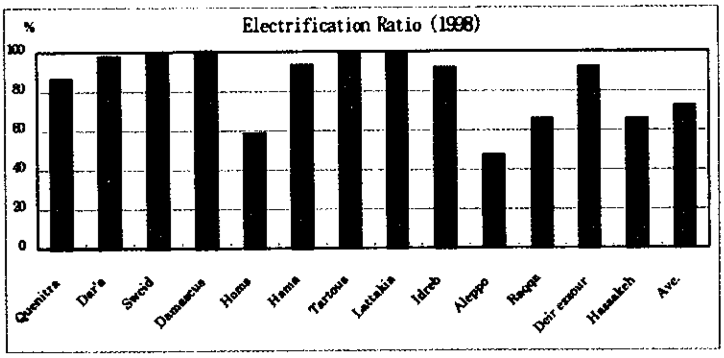
Syria is a developing country and has been exerting much effort to develop the infrastructures including the electric power supply and the traffic systems. However, as for rural electrification in particular, electrification rates in rural villages scattered over vast regions vary from place to place. The year-to-year state of electrification of the administrative units is shown in Fig. 2.4-3. Up to the end of the first half of the 1980s, electrification was pursued positively. From the latter half of the 1980s to the present, the numbers of the electrified units are low. One cause of this drop in the electrification efforts was the need of electric power development. The government gave the priority to this important task to eliminate power shortage. Another cause is the virtual completion of electrification in many regions.



Source : Electric Power demand & Rural Electrification in Syria
(Eng. Suhyan Allaw : Assistant Minister Electricity)

Fig.2.4-3 Transition of number of electrified district

The present state of electrification by region (large city, governorate) is as shown in Fig.2.4-4. The electrification rates have reached near 100 % in half of the regions. Of the remaining regions, Aleppo region has about 50% of electrification.



Source : Interior data of the Ministry of Electricity

Fig.2.4-4 Electrification Rate by Prefecture

3. Feature of Un-electrified Villages in Syria and Outline of Project Site Village

On the features of Aleppo region wherein the villages covered by this project, the general features of the mountainous area (area to the northwest of Aleppo) and the plain area (area to the south of Aleppo) are described. Then the four villages covered by the project are outlined.

3.1 Features of un-electrified villages in Syria

3.1.1 Outline of the villages in the mountainous area

In the mountainous area around Aleppo, there are two types. One is completed plantation of fruit tree such as olive and so on. The other is no trees such as olive etc and exposed the surface of the mountain. The occupation of the area therefore, one area is doing mainly the pomiculture (an olive is primary concern, including an almond and a pistachio). The other is doing a small-scale pasturage along with growing cereal and vegetables on a small scale. Economically, the area where is possible to do pomiculture is regarded as being abundant more than the other area.

Even if it is an un-electrified village, some households possess TV and use them with car battery as a power source and for charging, the tractor engine is used. For the cooking, butane gas is mainly used, for the heating, gas oil is used and a kerosene lamp or a partly, butane gas lamp are used for the lighting. The branch from the olive trees is used as the firewood and dung of livestock dries up and used as fuel.

As for the house, a square type is popular and built by piled cutting stones and the inside is completed with the mortar. The main room is about 5m x 10m and height is about 3m, high ceiling. A terrace or a rooftop is prepared as the place for the processing work of the agricultural products.

3.1.2 Outline of the village in the plain

In the plane area, some villages carried out systematic irrigation and some villages depend only on the rainfall for their agriculture. There is a big difference in the yield for the unit tillage in the irrigated and non-irrigated area and thus causes the big difference on their income. In the eastern part of Aleppo, irrigation cannel from the Euphrates River is serviced and the wide cultivated land is spreading.

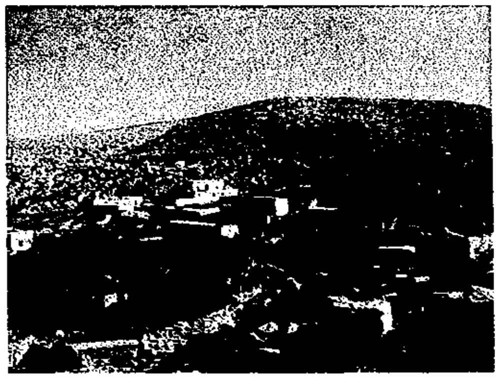
On the other hand, in the southern part of Aleppo, the area where is like Jabal al Hoss is irrigated by the underground water. Outside of that area, only depend on the natural rainfall and small wells for watering. The growing of a cotton, an olive, an almond, vegetables and so on are cultivated in the area which an irrigation facilities are provided and the large scale pumping can work. The machines such as tractors, sprinklers, and combines are introduced in the wide cultivated land. However, the development area like Jabal Al Hoss and around of it, villages depend on small-scale agriculture and the pasturage (the nomads) mainly sheep and goat. Because, cow breeding needs a lot of drinking water and feed, so that, breeding is difficult in the small water quantity area.

Generally, mountainous village has smaller cultivated area and deeper underground water level than the plain area. Therefore, the mountainous village tends that harvesting volume per unit area is less and income is lower than the plain area. Moreover, density of houses in village is comparatively higher than the plain area because of limited village area. In any mountainous area and plain area villages have more than 80-100 houses are electrified by the grid extension in advance but villages with tens of houses are often left. The grid line didn't extend more than 10 years even after electrified 2-3km ahead. The request of electrification is very strong in those areas.

3.2 Outline of village where systems were installed

①Katoura

In Katoura, stone-built houses are scattered on hilly land on both sides of the road. There are 25 households and the population is 200 persons. A western part of Katoura basin, which is stretching in front of this village, is the agricultural land of the village. It is a fertile land of red soil, and high yield can be expected.



As the village is close to Aleppo, the residents show strong inclination towards the city. They have been eager about education. Girls are also expected to receive higher education.

②Zarzita

Zarzita is located on the peak. The village was established about 100 years ago by utilizing artificial wells of the Roman period in the remains of olive plantations.

In this village, stone-built houses are relatively concentrated. At present, the number of households is 40 and the population is 400 persons.

As for the drinking water, the residents stock rainwater or purchased water in artificial wells and wells of the Roman period. Deep valleys are formed on the southern side and the western side of the village, and the land on these sides cannot be used as agricultural land. Along the road to Katoura and Fedre, a relatively flat land stretches and is used as agricultural land. The agricultural land areas of the households vary from 1 to 30 ha. As these agricultural land hold much limestone, the yield depends on weather. Some farmers have tractors.

③Fedre

Fedre is topographically similar to Zarzita. Most of the houses in this village are stone-built, but there are some mudded hat houses. At present, the number of households is 13, and the population is 50 persons. As for drinking water, just like Zarzita, the residents stock rainwater or purchased water in artificial wells and wells of the Roman period. As the cultivated land areas of the village are small and the relations with the towns are remote, agriculture is rather labor-intensive.

④Rasem Al Shikh Kalif

Kalif is located in the southernmost part of an extensive upland called Jabal Al Hoss to the south of Aleppo City. A straight road runs to the south from Aleppo. Mechanized agriculture is practiced extensively on both sides of the road. The land is highly cultivated with soybean and wheat. In

summer, culture of cotton is done in some tracts of land where water is available. An extensive steppe stretches in front of the village. The houses on the flat land are mainly mudded houses. Many houses of this village are mudded ones. The number of households is 25 and the population is 170 persons. Here the precipitation is low in winter and the groundwater is brackish. Hence the farmers specialize in stock farming, except one farmer that specializes in agriculture. In winter, rainfalls in the steppe and grass grow there. Hence the farmers engaging in stock farming graze their sheep and goats in the steppe. In summer, grass withers and feed for the stock is not available. The farmers take their stocks and families and move to the north near to Aleppo City. They live in tents and graze their stocks. During this period, the population of the village decreases drastically.

Table 3.3-1 Comparison of objective four villages

(Exchange rate at 1998 : 1US$ = 46SP)

	Zarzita	Fedre	Katoura	Kalif
Location	30km Northwest from Aleppo	Same as Zarzita	Same as Zarzita	50km Southeast from Aleppo
Topography	Mountainous	Mountainous	Plain to Hilly	Plain
Number of houses 1997	40	13	25	25
Number of households	40 (increasing)	13 (decreasing)	25 (increasing)	25 (increasing)
Average number of person(1997)	Man 4.8 Woman 4.6 Total 9.4	Man 2.8 Woman 3.4 Total 6.2	Man 4.6 Woman 3.6 Total 8.2	Man 3.3 Woman 3.4 Total 6.7
Total number	376	81	205	168
Less than 12	39%	48%	36%	45%
More than 60	4%	7%	5%	6%
Main occupation	Agriculture Wage working	Agriculture Wage working	Agriculture Wage working	Wage working Agriculture
Main cropper	Wheat, Barley Olive	Wheat, Barley Olive	Wheat, Barley (Olive)	Wheat, Barley
Main Livestock	Cow, Sheep/Goat Chicken	Cow, Sheep/Goat Chicken	Cow, Sheep/Goat Chicken	Sheep/Goat, Chicken
Average number	Cow 2.8 Sheep/Goat 20	Cow 5.3 Sheep/Goat 32	Cow 3.5 Sheep/Goat 40	Cow 0 Sheep/Goat 20
Water	Rainwater, Well Purchasing	Rainwater, Well Purchasing	Rainwater, Well Purchasing	Well(saline) Purchasing
Illumination	Kerosene lamp Gas lamp	Kerosene lamp Gas lamp	Kerosene lamp Gas lamp	Kerosene lamp
Dwelling wall roof	Stone Plane(concrete	Stone Plane/Coned	Stone Plane(concrete)	Clay Plane(wood)
No. of room	2 to 5	2 to 3	2 to 4	1 to 3
Road	Paved	Unpaved	Paved	Unpaved
Nearest town	Dartazze (7km)	Dartazze (9km)	Dartazze (5km)	Abu AlZuhur (5km)
Average income	77,000SP/year	41,500SP/year	72,000SP/year	68,500SP/year
Per adult *	14,400SP/year	14,900SP/year	14,900SP/year	20,900SP/year
Expense for food	61%	53%	57%	...
For fuel	6.1%	6.8%	9.0%	4.4%
For lighting	2.3%	3.6%	4.3%	1.5%

4. Village Electrification Powered by PV Systems

The demands for electricity were assumed for Zarzita, Fedre, Katoura and Rasem Al Shikh Kalif by considering the layout of the dwellings, layout of rooms in the dwellings, family configurations and incomes of households of the respective villages. On the basis of these assumption, systems were designed. A centralized PV system was installed in Zarzita, and individual PV systems were installed in other villages.

4.1 Centralized PV System

4.1.1 Determination of system capacity

(1) Assumption of demands in Zarzita

Demands were assumed for the daytime and the nighttime by assuming the use of PV system, considering the use of appliances by the residents and their requests. The resulting estimates were as follows:

Table 4.3-1 Assumption of power demand for the centralized system

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Night	Light							
	House	20(W)	200	4,000	0.8	5,000	6	30.00
	Mosque	20(W)	6	120	0.8	150	2	0.30
	Radio cassette	Radio:4(W)	40	160	0.8	200	3	0.60
		Cassette:15W		600	0.8	750	2	1.50
	TV	Color:70(W)	25	1,750	0.8	2,188	6	13.13
		Mono:40(W)	15	600	0.8	750	6	4.50
	Street lamp	10(W)	20	200	0.8	250	13	3.25
Consumed power during night								53.28
Day	Lighting school	20(W)	10	400	0.8	500	1	0.50
	R/cassette	Radio:4(W)						
	house		40	160	0.8	200	2	0.40
	school		1	4	0.8	5	2	0.01
	Cassette	Cassette:15(W)						
	house		40	600	0.8	750	2	1.50
	school		1	15	0.8	19	2	0.04
	Fridge (common)	1,000(W)	4	4,000	0.8	5,000	1.5	7.50
	Washing machine (40 units)	160(W) (1 time /week)	6	960	0.8	1,200	2	2.40
Consumed power during day								12.35

(2) Capacity of PV array and battery

Based on the above-mentioned demands, the minimal daily insolation of the month (3.3 kWh/m^2·day) is used as the standard and PV system was designed. As a result;

PV array capacity P (kW) : 35kW

Battery capacity : 336(kWh) (12V-200Ah/battery --- 20 series x 7 parallel)

4.1.2 Configuration of centralized PV system

The configuration of centralized PV system of Zarzita ins as shown in Fig.4.3-1. The system consists of ① PV arrays, ② batteries store DC power generated by PV array. ③inverter changes DC into AC of the commercial frequency. ④controller controls PV system operation. ⑤ distribution line facilities supply AC power to the respective households.

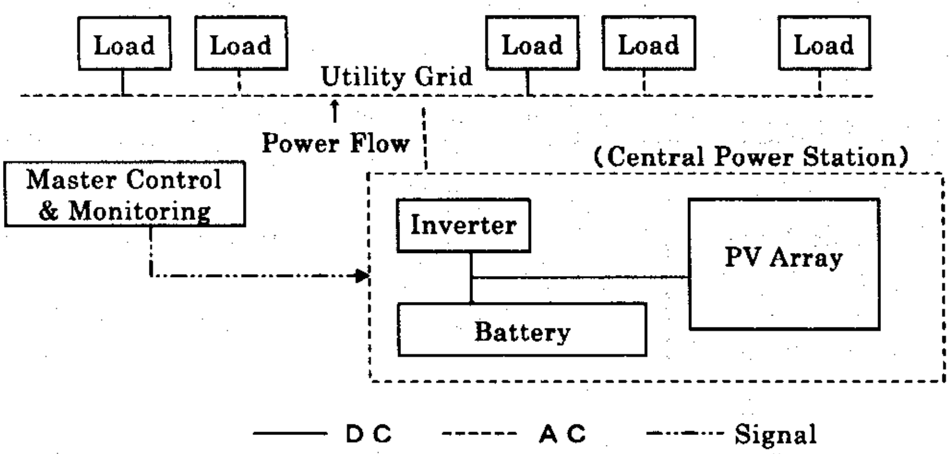


Fig.4.3 -1 Configuration of Centralized PV System

4.1.3 Situations of demand and supply and system operation

The measuring instruments used in the centralized PV system include the voltmeters, ammeters and watt-hour meter that are installed in the control room, and the watt-hour meters installed in the respective customer households. In addition to them, data loggers, which can precisely measure the conditions of consumption, are installed in four typical households. The demand and supply conditions of the entire system are analyzed on the basis of the data collected by the respective measuring instruments. The transition of power demand and supply from November 1997 to October 2000 is as shown in Fig.4.3-2. Power consumption was beyond the design (approx. 4,000kWh/2 months) after 2 years from the start of operation. Moreover, in summer 1999, consumption was largely increased than that of usual use. However, even in winter season that insolation is low, night demand can be covered. Therefore, initial design is satisfied.

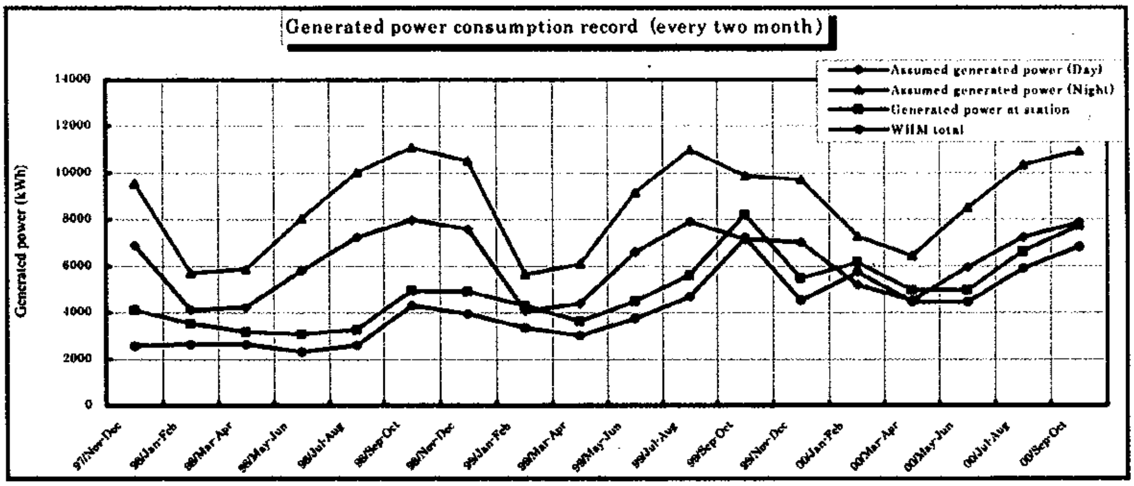


Fig.4.3-2 Transition of actual power supply and demand for centralized system

4.2 Individual PV System

4.2.1 Determination of Scales of the Respective Systems

The individual PV systems were installed in three villages; Fedre (15 households) and Katoura (24 households) in mountainous areas, and Kalif (24 households) in a plain. The demands were assumed on the results of the social environment surveys of these villages and by considering economic conditions of the villages, number of electric appliances in use, capacities and durations of use of such appliances.

Table 4.2-1 Assumptions of power demand in Fedre

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Nighttime	Light	20	3	60	0.8	75	3	225
	Radio	4	1	4	0.8	5	3	15
	Cassette	15	1	15	0.8	19	2	38
	TV B&W	12	1	12	0.8	15	3	45
Consumed power								323

Table 4.2-2 Assumptions of power demand in Katoura

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Nighttime	Light	20	3	60	0.8	75	4	300
	Radio	4	1	4	0.8	5	3	15
	Cassette	15	1	15	0.8	19	4	76
	TV B&W	12	1	12	0.8	15	3	45
Consumed power								436

Table 4.2-3 Assumptions of power demand in Kalif

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Nighttime	Light	20	4	80	0.8	100	4.5	450.0
	Radio	4	1	4	0.8	5	3	15.0
	Cassette	15	1	15	0.8	19	2	37.5
	TV Color	50	1	50	0.8	62.5	3	187.5
Consumed power								690.0
Daytime	washing machine	160	1	160	0.8	200	2	400.0
Consumed power								400.0

Based on the demand assumed, each PV system was designed. As a result, each system capacity was calculated as follows.

	PV array capacity	Battery capacity
Fedre	200 W	2.4 kWh
Katoura	300 W	2.4 kWh
Kalif	500 W	7.2 kWh

4.2.2 Configuration of the Individual PV Systems

The individual PV system mainly consists of a PV array and storage batteries. DC electricity is supplied to electric appliances through a controller. To supply the DC power, an inverter is also used. The system configuration is as shown in the diagram below.

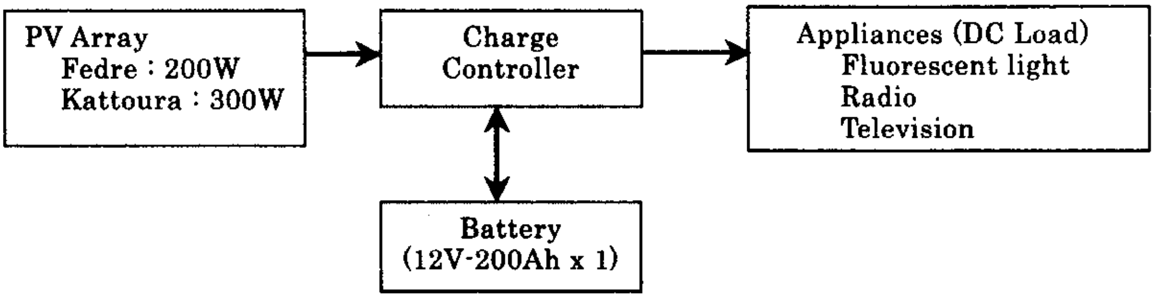


Fig 4.2-1 Configuration of DC system

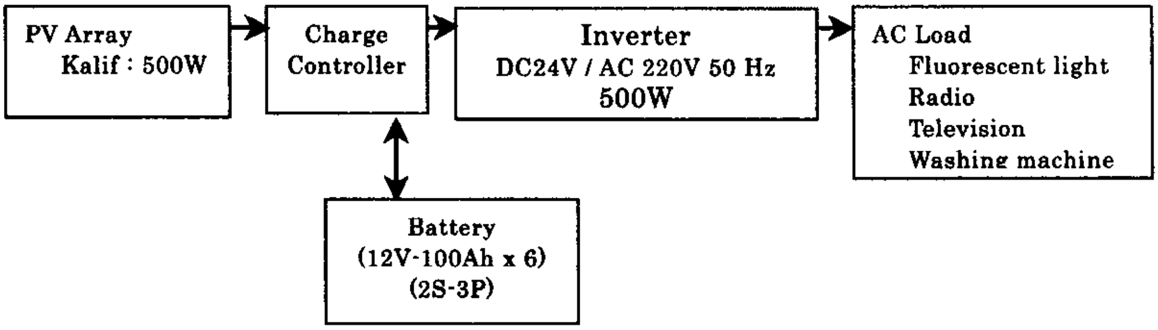


Fig.4.2-2 Configuration of AC PV System

4.2.3 Situation of power supply and demand

The individual PV systems are not provided with a watt-hour meter. However, data loggers are provided on the systems of some customers. The state of demand and supply must be estimated on the basis of the data collected by these data loggers. The demand and supply conditions of the customers having data loggers of the respective villages are as follows:

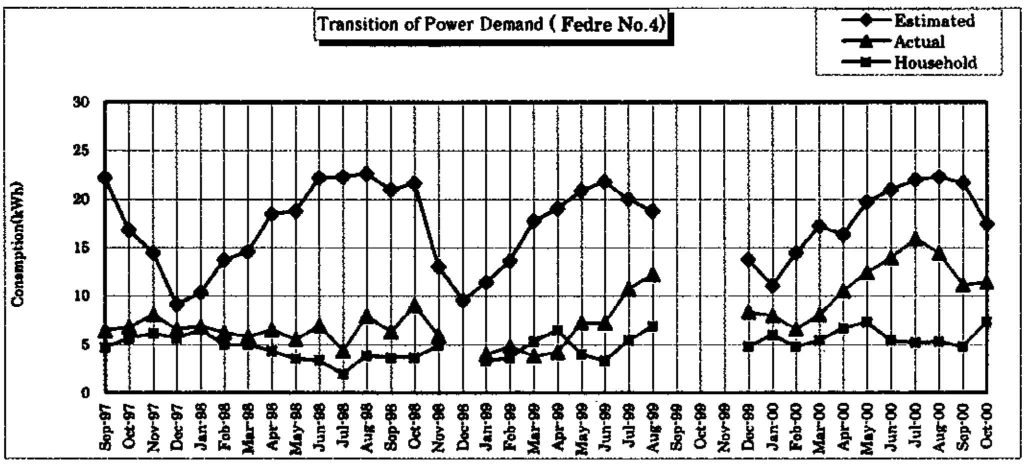


Fig.4.2-3 Situation of power supply and demand on Fedre No.4

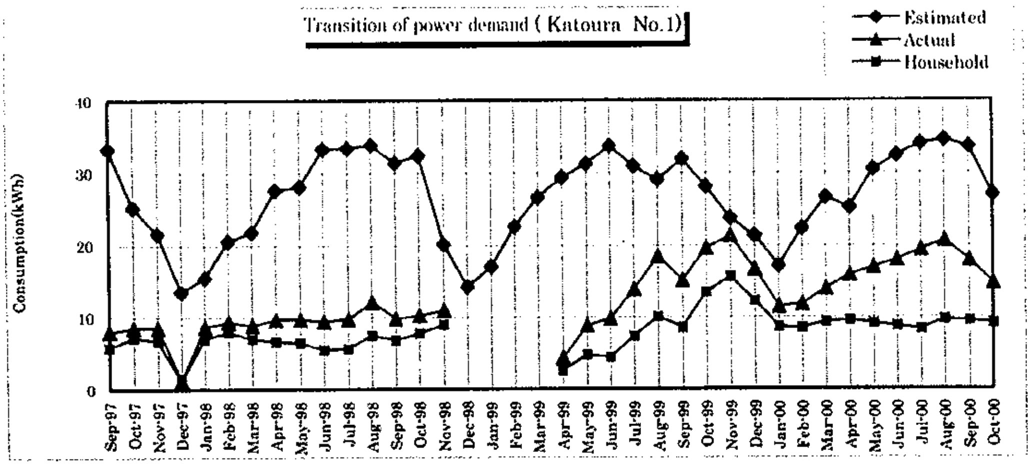


Fig.4.4-3 Situation of power supply and demand on Katoura No.01

From these figures, with regard to the demand and supply condition, the individual PV of the respective villages have a margin that allows stable operation for a longer period in comparison with the centralized PV system. The major appliances are lighting, radio and TV set. In these figures, data were not accurately recorded for the system of Katoura in December 1997, and for the systems of Fedre and Katoura in December 1998 and from January to March 1999, due to the output drop of the batteries of the data loggers. Except these months, the actual records of use in Fedre and Katoura were substantially lower than the assumed power generated, leaving a margin of supply capability. Similarly, the data of AC 220V power of the system of the representative household in Kalif, are shown in Fig 4.2-5.

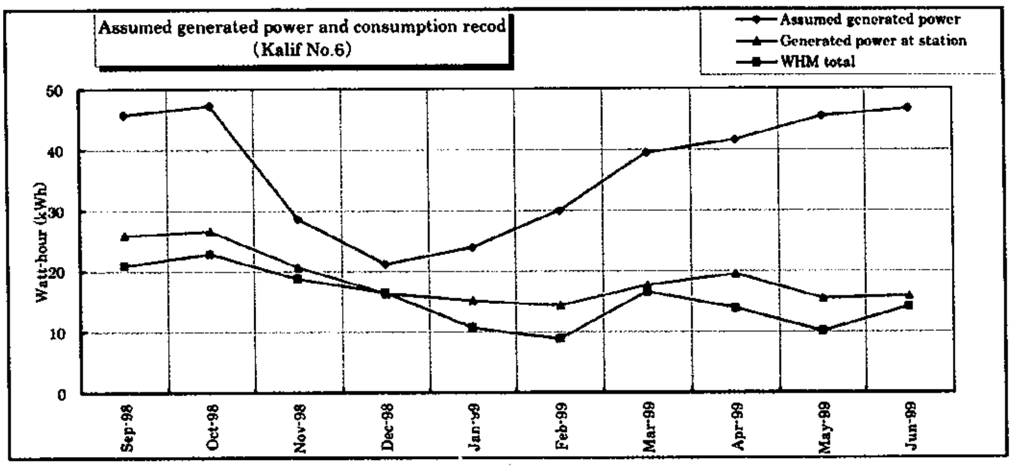


Fig.4.2-5 Situation of power supply and demand on Kalif No.06

As described above, the individual PV systems of the respective villages have a margin in supply capability except in winter. One future task is to find some measures to utilize it efficiently.

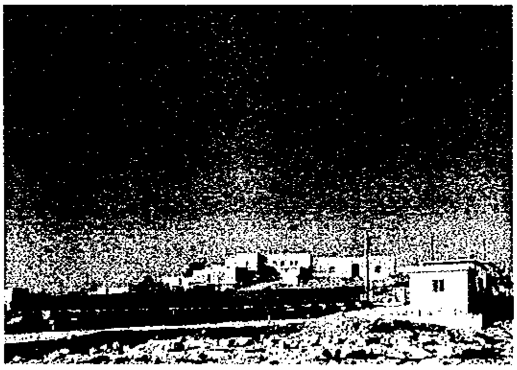
4.3 Operation and maintenance

Regarding the centralized system and the individual system, PV systems can make automatic operation while the controller functions to protect the batteries. The maintenance and inspection program comprises the routine inspection and the periodical inspection.

- In routine inspection, an emphasis is placed on visual inspection. PV system is checked for abnormal sound, abnormal smell and heat generation. PV system is cleaned as well when necessary.
- In periodical inspection, the operational tests of the components, which cannot be made in routine inspection, are given.

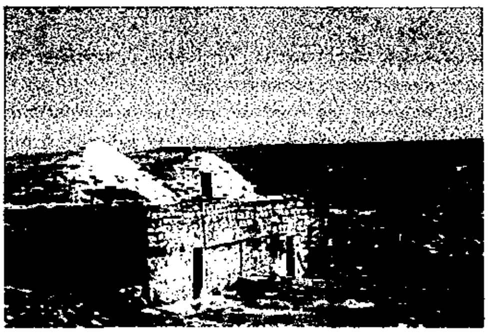
Based on the state of maintenance work, manual for maintenance was made and revised by recording check point and improving point. When trouble is happened, it should be repaired and influence of trouble and damage is removed to keep the function of PV system as soon as possible. As a result, every introduced system is continued operation without any trouble.

<Photos of the village electrification system>

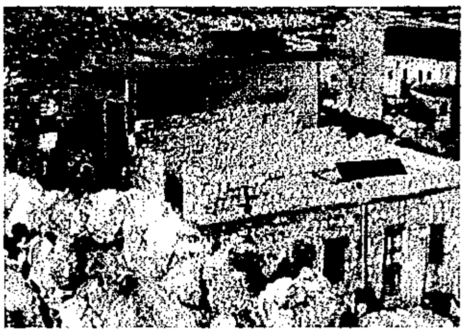


Centralized svstem in Zarzita

Individual AC svstem in Kalif



Individual DC 200W svstem in Fedre



Individual DC 300W system in Katoura

5 . Water Pumping/Desalination system powered by PV system

The water pumping system powered by PV system was installed in Zarzita, and the water pumping / desalination system in Rasem Al Shikh Kalif, respectively.

5.1 Zarzita PV Pumping System

5.1.1 Selection of the Installation Site of the Water Pumping System

In Zarzita, there are two candidate wells for water pumping system. One is in front of the mosque of the village, and the other is 500m in depth along a road leading from the village to Fedre. These wells were bored by the Water Authority of Aleppo. However, the quantity of these two wells was less than10 m^3/hr and not meets the Water Authority standard. t able to use these wells. The pumping test of the existing wells was carried out. The well in front of the mosque was as little as 0.2 m^3/hr. On the other hand, regarding the well beside the road to Fedre, pumping was continued at a quantity of 1m^3/hr for 6.5 hrs, but water level did not drop below −160m. When the quantity is at 2m^3/hr, after four hours of continuous pumping, the water level did not drop below −177m, and the water level restored after about three hours.

As a result, it was decided to make PV water pumping on the well beside the road to Fedre. Water analysis of this well showed there is no problem about using this water as drinking.

5.1.2 Outline and configuration of water pumping system

The capacity of pumps and arrays are designed to pump up more than 10m^3/day in summer, and the capacity of transit tank and hi-tank are designed to be 10m^3 and 30m^3 respectively considering the fluctuation of load.

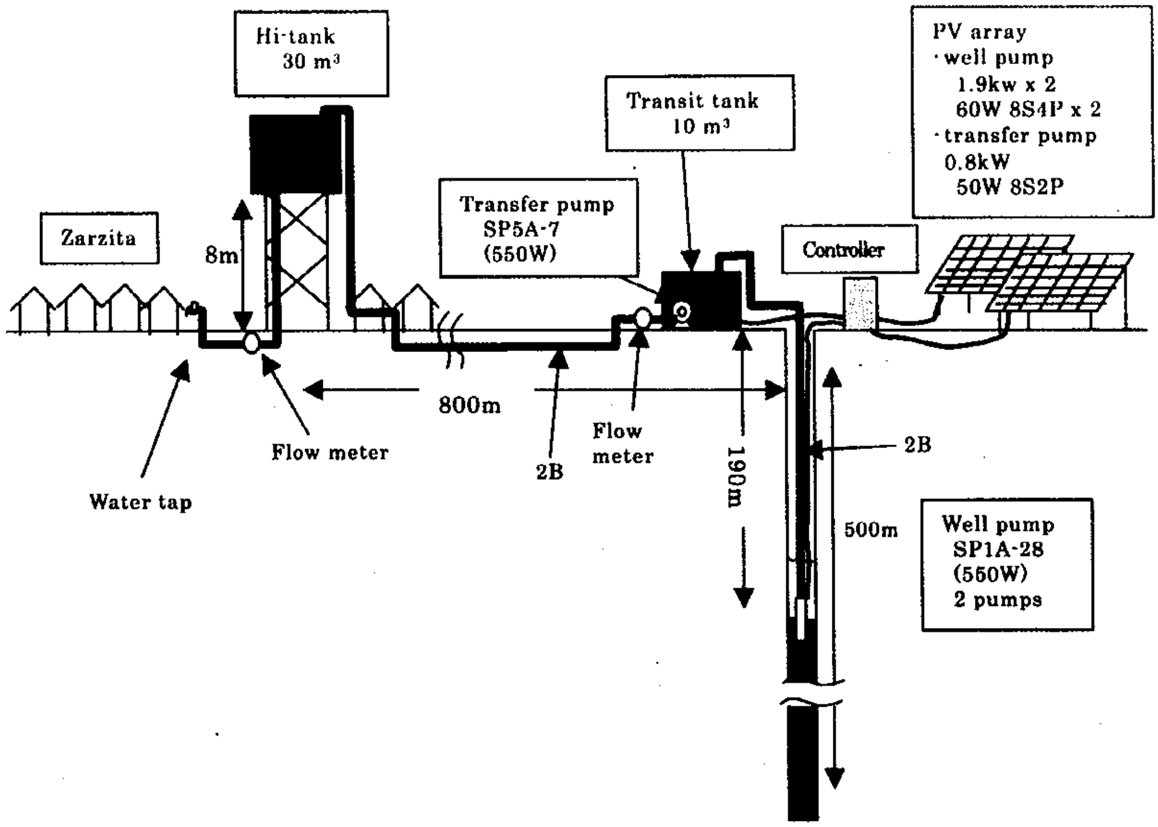


Fig.5.1-1 Overview of Zarzita PV pump system

5.1.3 Situation of water supply

Trial operation began on April 1998, and the operation shifts to the selected operator by the Aleppo Water Authority from September. From October, the selected operator records the reading of flow meter and well water level every day. One-day water quantity obtained by subtracting previous day's total volume from totalizer and transition of water quantity is shown in Fig 5.1-2. From this fig., the water quantity in winter is small because of rain resulting only $4m^3$/day on average. However, it becomes 8～$10m^3$/day in the other seasons and initial design is satisfied.

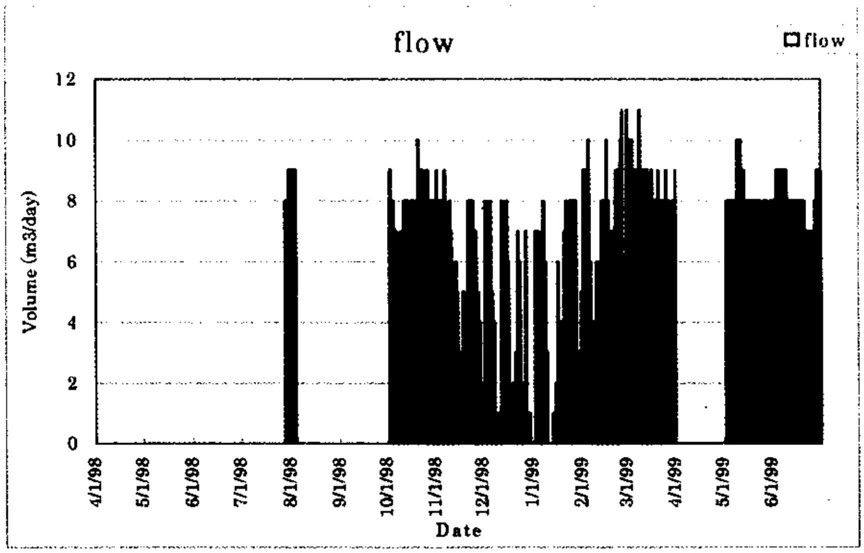


Fig.5.1-10 Transition of one day pump up water quantity

5.1.4 Monthly change of pumped and supplied water quantity

Monthly change of the amount of pumped water and supplied water is shown in Fig. 5.1-3. It is shown that the amount of the pumped water meets 250m^3 per month in summer because of insolation increased. On the contrary, the amount of the pumped water declines 160m^3 in winter. The amount of pumped water in spring and summer in 2000 is small compared to that of the same time in last year. This is the reason why one out of two pumping controller broke and one pump was not working. After the controller was repaired by SSRC/HIAST, two pumps were working normally.

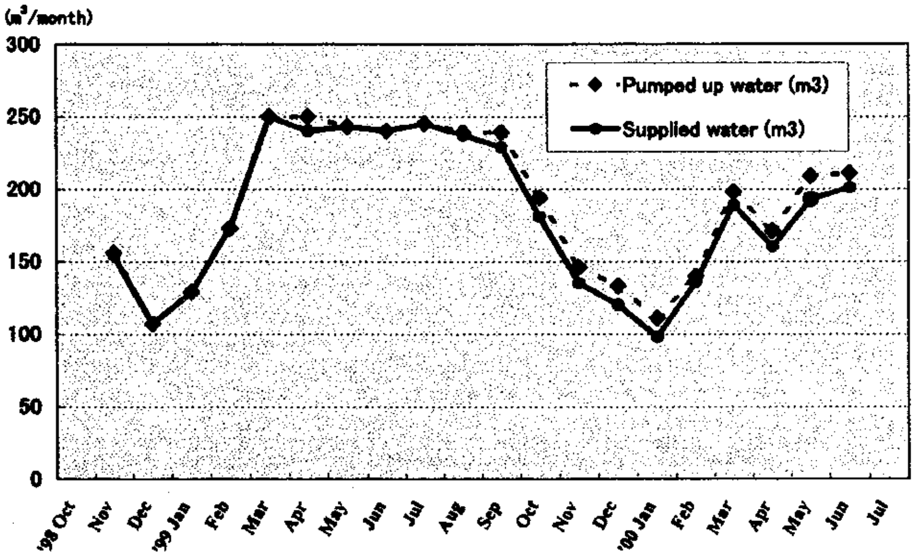


Fig. 5.1-3 Monthly change of the amount of pumped water and supplied water

5.1.5 Maintenance

Since this system is totally operated automatically, there is no daily operation activity but, two or three times a week of normal maintenance is needed. At the same time, cleaning of PV panel surface and recording of well and tank water level is executed. On the other hand, on the periodical maintenance, water quality test (once or twice a year) and pumping test (once or twice a year) is carried out to check pumping quantity and deposition on tank internal surface (once or twice a year) is also checked. At present, generation of bacteria etc was happened initially. The bacteria generation was caused initial insufficiency of cleaning, and never happened again after disinfection.

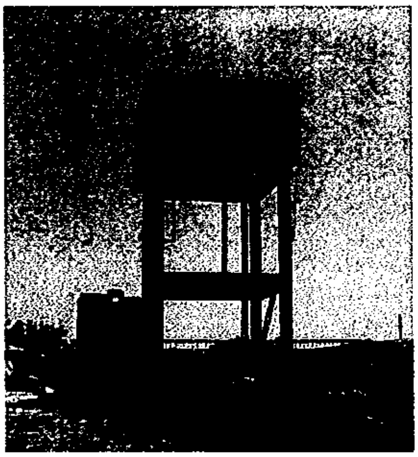
5.1.6 Conditions of water demand and supply after installation

The water pumping system powered by PV has been operating smoothly since the commencement of the operation. 8～10m³/day of the water pumping quantity is available in the clear day. In the rainy season or winter from November to March, still 8m³/day is available in clear day. During this period, the system can provide a mean quantity of 4～5 m³/day. In particular, in winter, rainwater is stored in private or common artificial wells. Hence sufficient supply of drinking water is secured.

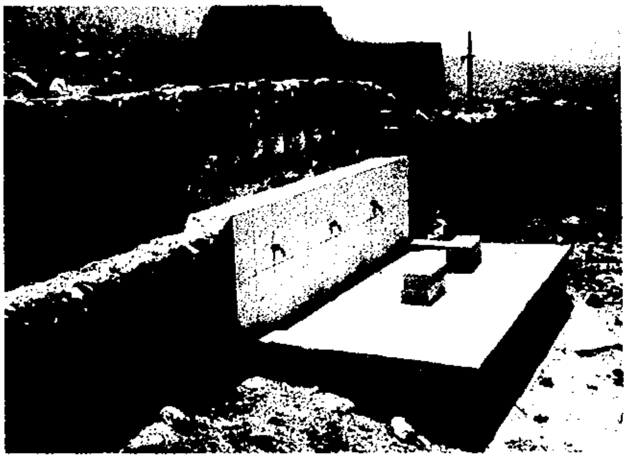
After the commencement of operation of the system, 14 households out of 40 households were randomly sampled to investigate their purchase of water in summer. The quantities of purchased water were halved in comparison with those before the installation of the system. The pumping quantity in summer for 14 households was 588m³ (8m³/day x 30day x 7months x 14/40 (the ratio of the households)). This quantity fairly exceeds 420m³ that was the purchased water quantity before the installation of the system. Thus the water demand and supply balance can be maintained adequately.

<Photos for Water Pumping>

General View of Water Pumping System



Water Supply Tank in Zarzita



Water Service Taps in Zarzita

5.2 Desalination System in Rasem Al Shikh Kalif

On Rasem Al Shikh where initially planned to install the desalination system, when the second year survey was made, it is found that new fresh water well was drilled. Therefore, the alternative installation point was selected. As a result, Kalif was nominated to install water pumping / desalination system.

5.2.1 Outline and configuration of the desalination system

The demand for fresh water had been investigated in Rasem Al Shikh before Kalif was chosen as the installation site, and found to be about 10 liter / person / day. Though there was no investigation data about Rasem Al Shikh Kalif, the fresh water demand for the village was thought to be similar to that of Rasem Al Shikh. Therefore, the requirement of the village for fresh water was assumed to be about $2m^3$ per day because the population was about 170. On the other hand, new well was bored and test pumping showed that the water depth of the well is $-40\sim-50m$ and about $20m^3$/day of raw water can be pumped up for desalination.

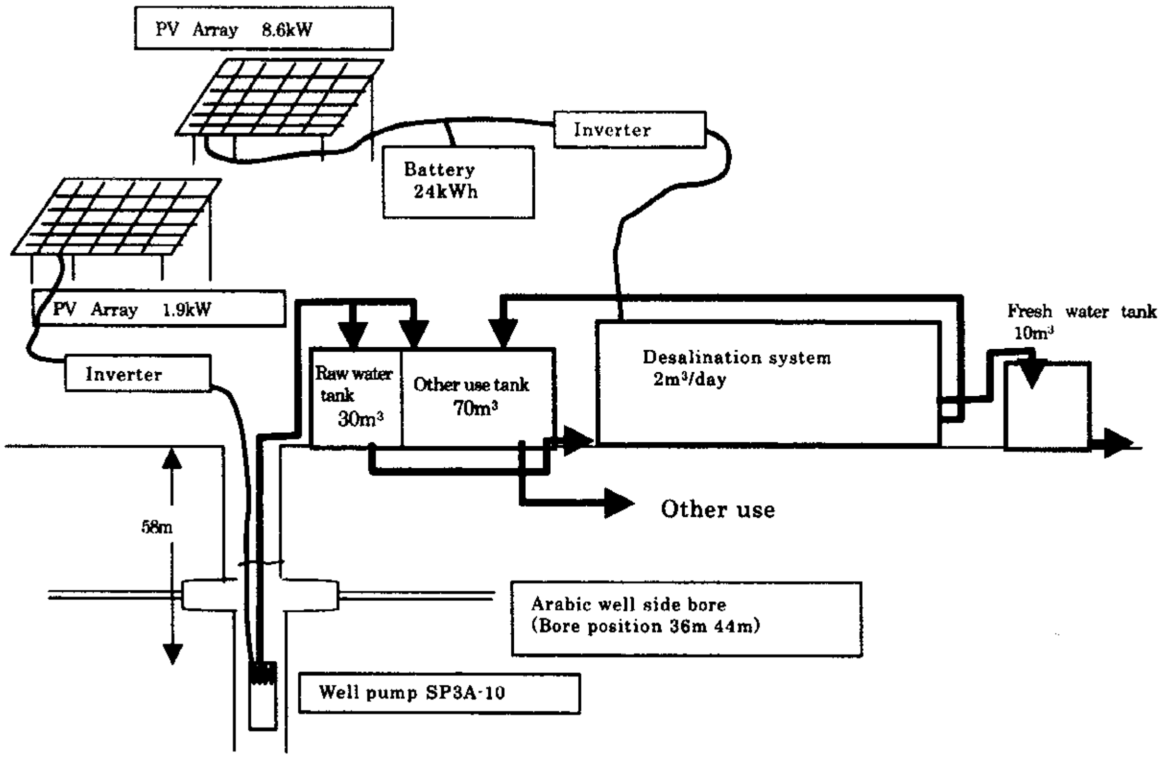


Fig. 5.2-5 General configuration

5.2.2 Daily average quantity of desalinated water production

The daily average production of desalinated water of Kalif desalination system is shown in Fig. 5.2-10 from the start of operation. This shows that about 1.5m^3 of fresh water was produced in winter, whereas about 4m^3 for summer. The reason for the water quantity decrease in winter is that rate of operation is down because of cloudy weather.

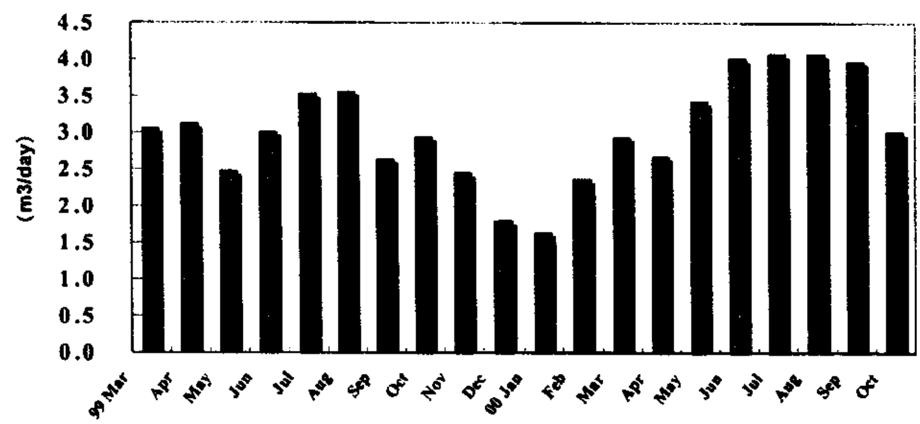
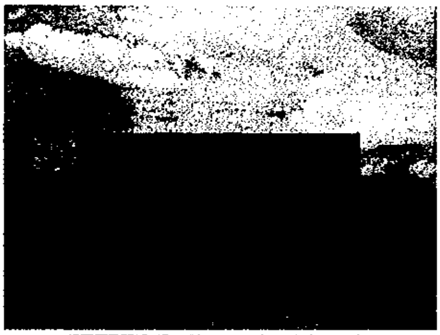


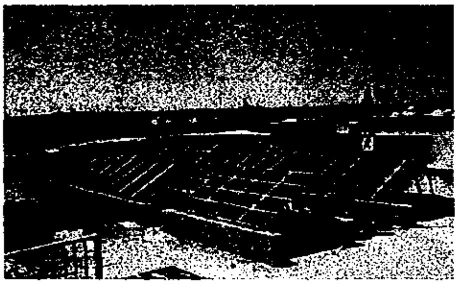
Fig 5.2-2 Daily average production of desalinated water

<Photo for desalination system>

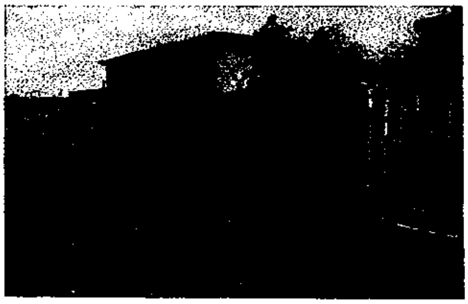
Whole view of desalination in Kalif



Desalination system



PV array



Water tap for distribution

5.2.3 Operation and Maintenance

To prepare for replacement of major components of the desalination system, reverse osmosis membranes, high-pressure pumps, etc. have been furnished, as spare parts. With these spare parts, the desalination system should be able to be operated and maintained without any large expenses for ten and more years. As for chemicals and expendables other than these spare parts, market survey was carried out in Syria and found that such chemicals and expendables can be procured by purchasing Syrian or foreign products. On the operation and maintenance, manual was made and distributed the copies of the manual to the parties concerned.

5.2.4 Water Supply Conditions after the Installation of the System

In winter, freshwater can be produced 1 m^3/day. As the population is about 170 persons, about 6 liters of drinking water per person can be supplied from this fresh water. In summer, freshwater can be produced 5 m^3/day. If this water is stored earlier in underground tanks, the supply to the residents will be increased. However, about 80% of the residents start nomadic herding. Hence the population drops drastically. Thus, it is important, in future, to share the large quantity of surplus freshwater with neighbor villages to effectively utilize it.

6. Operation Management and Organization System

As for PV system (for power supply and water supply) installed in this project, a maintenance/operation system is established so that a consistent service can be provided after completing the project. According to the regulation of electricity/water supply in Syria, only the Aleppo Electric Authority and the Aleppo Water Authority can handle power supply and water supply, respectively. Therefore, the both Authorities take charge of the activity of the maintenance and management.

6.1 Organization of maintenance management for the introduced systems

With regard to village electrification system and water pumping / desalination system installed in this project, under the technical assistance of SSRC/HIAST, the operation and management were committed to the Aleppo Electric Authority and the Aleppo Water Authority, which are public establishments in Syria, and the written agreement was exchanged. The agreement was approved by the Aleppo Water Authority in July 1999, and was approved by the Aleppo Electric Authority in January 2000, respectively.

6.1.1 Outline of the agreement

The following is the outline of the agreement on maintenance/management of the systems:

- SSRC/HIAST and the both Authorities shall establish a management committee for maintenance/management of the systems, respectively.
- Management committees are responsible for operating the systems, analyzing the operation data, expanding the existing systems, approving the use of the equipment, and disclosing the appropriate technologies obtained through the experience during the operation of these systems.
- Both Authorities are charged with all responsibilities for operating and maintaining the systems.
- Fees shall be considered and set by the both Authorities and shall be collected immediately after contracting with customers who need public services.
- For new customers who need electricity and/or water, the decision shall be made based on the opinion of the management committee.

6.1.2 Management of village electrification system by the Aleppo Electric Authority

(1) System management committee

The system management committee consists of the Aleppo Electric Authority and SSRC/HIAST:

Members of the management committee:

Chairman:	Eng.Mohamad SAAD	President of the Aleppo Electric Authority
Member:	Dr.Riad SABOUNI	SSRC/HIAST, PV laboratory, Chief
Member:	Eng.Yasel SHAHEED	SSRC/HIAST, PV laboratory
Member:	Eng.Jamal Haj BAKRI	The Aleppo Electric Authority, Dartazze Economy Unit, Chief

The committee consists of two members from the Aleppo Electric Authority, and two members from SSRC/HIAST. The chairman of the committee is the Director General of the Aleppo Electric Authority. The committee maintains and manages the systems introduced for a long period, through operating the village electrification systems in four villages and analyzing maintenance & operation data. As for the support to a new customer who needs public services, the committee should consider how to support the customer. If necessary, the Aleppo Electric Authority bears the expenses for expanding or adding systems, and SSRC/HIAST procures necessary materials and equipment.

(2) Organization of the Aleppo Electric Authority for system management

Before the system management was shifted to the Aleppo Electric Authority, it is necessary to get approval by PEDEEE (Public Establishment for Distribution & Exploitation of Electrical Energy), which controls power distribution businesses in Syria. PEDEEE includes setting fees for electricity supplied from PV system.

In the Aleppo Electric Authority, all the systems of four villages should be managed by Economy Unit of the Aleppo Electric Authority in Dartazze. The Aleppo Electric Authority nominates engineers and/or technicians and educates them under the instruction of SSRC/HIAST.

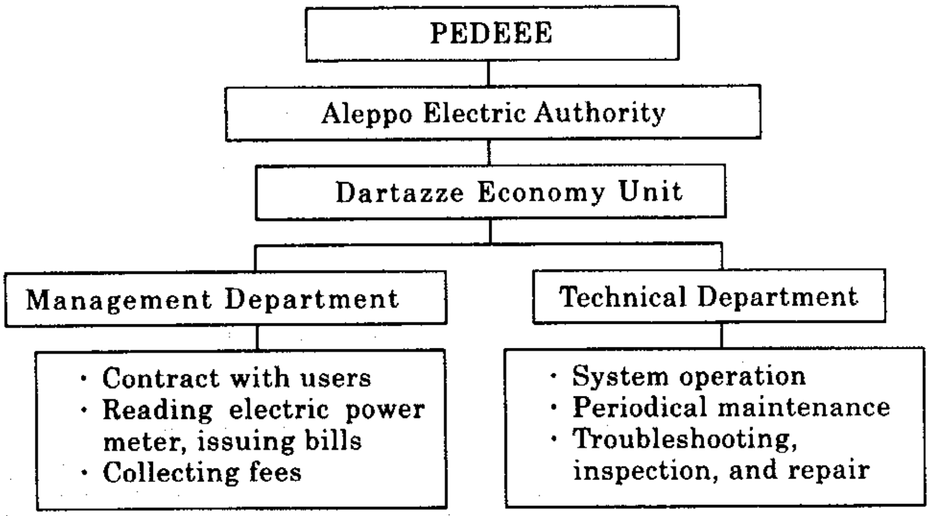


Fig.6.1-1 System management chart of the Aleppo Electric Authority

(3) Setting electricity fees

Originally, the electricity fees for PV systems introduced in this project were considered by PEDEEE and afterwards the consideration was committed to the Aleppo Electric Authority. The results of that consideration with SSRC/HIAST were reported to PEDEEE in September 2000 and fee was revised by PEDEEE as 0.75SP/kWh for all villages in January 2001. In Zarzita, there is an electric power counter. So the reading of the counter is considered as the consumption. For Fedre, Katoura, and Kalif, fixed fees are applied. The amount of power generated is calculated on the assumption of 10 hours of sunshine a day. According to this calculation, fee is charged for every two months.

6.1.3 Management of the water pumping/desalination system by the Aleppo Water Authority

(1) System management committee

The system management committee is similar to the Aleppo Electric Authority.

(2) Water pumping/desalination system management organization by the Aleppo Water Authority

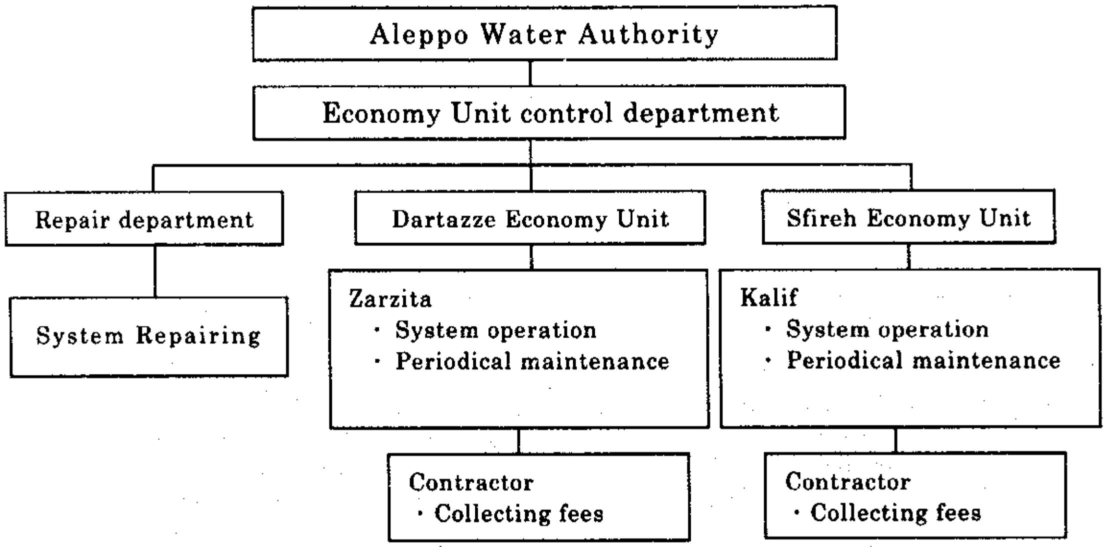


Fig.6.1-2 System management chart by the Aleppo Water Authority

(3) Training of technicians involved by the Authority

Training two persons of Economy Unit in Dartazze was completed in July 1999. One person is operating and maintaining the system as a dedicated technician. Training three persons of Economy Unit in Sfireh was started in February 2000. One of them is living in Kalif and has been trained since trial operation of the desalination system. Now, the dedicated technician in Kalif executes operation and management of the system.

(4) Setting fees and collection

In Zarzita and Kalif, contractors were elected. First, according to the consumption, the contractor charges water fee to the users as an unit price of 7.0 SP/m^3. Then the contractor pay water fees as an unit price of 6.5 SP/m^3 to the Aleppo Water Authority according to the consumption. In Zarzita, Economy Unit charges the contractor before collecting the water fees from users. According to the bill, the users pay an equal share of expenses in a family to the contractor. In Kalif, water is distributed to each family using a water tank truck at present. The total water amount is measured when water is supplied into the tank truck. The water fees for each family are calculated and charged when the truck distributes water to the water tank of each family: a water fee of 7 SP/m^3 plus usage fee of the tank truck.

6.2 Summary

(1) Management organization

Under the technical instruction of SSRC/HIAST, the Aleppo Electric Authority and the Aleppo Water Authority appointed the person responsible for operation and management respectively and the systems introduced in four villages are operated and managed by dedicated persons. As dedicated organizations, Economy Unit of the Aleppo Electric Authority in Dartazze is responsible for the village electrification systems introduced in Zarzita, Fedre, Katoura, and Kalif; Economy Unit of the Aleppo Water Authority in Dartazze is responsible for PV water pumping-up 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) Fees of electricity and water

a. Electricity fee

For fee of electricity, the unit price of 0.75SP/kWh was applied for all of the introduced PV systems. For Zarzita, the reading of the electric 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. For Zarzita, the usage amount of electric power varies greatly with users and therefore the charges to each user is different.

Table 6.4-1 Fee of electricity (SP/kWh)

Item	Zarzita	Fedre	Katoura	Kalif
Supply amount (kWh/year)	24,090	1,534	4,293	5,970
Electricity fee (SP/kWh : present fee)	1.26*	4.58	5.09	3.39
Average monthly fees (SP/user)	62	45	67.5	62.5
Electricity fee (SP/kWh) (Assumed average for 20 years)	1.56*	5.68	6.31	4.20
Average monthly fee (SP/user)	77.2	55.8	83.7	77.5

* Fee of electricity in Zarzita includes a fee of counter use (25 SP/month).

b. Water fee

According to the consumption, the contractor charges water fee to the users as an unit price of 7.0 SP/m^3. Then the contractor pay water fees as an unit price of 6.5 SP/m^3 to the Aleppo Water Authority. Based on the assumed water supply quantity, annual income for the Water Authority using a unit price of 6.5SP/m^3 is calculated.

Zarzita	2,640m^3/year x 6.5SP/m^3 = 17,160SP/year	
Kalif	900m^3/year x 6.5SP/m^3 = 5,850SP/year	
Total	23,010SP(500US$)(Fee per water consumption is 0.14US$/m^3)	

(3) System sustainability

With regard to the system management in the future, both Authorities can carry out management activity without any technical difficulty. However, there are large difference between the collected fees and substantial maintenance. Therefore, both Authorities subsidize to fill this difference. According to the system management activity by the both Authorities, sustainability of the introduced PV systems could be kept during their life.

7. Effect of livelihood Improvement by PV Systems Introduction

First, the effect of the introduction of cottage industry, which utilizes surplus electricity from the centralized system in summer in Zarzita, was evaluated. On the introduction of PV systems as an electrification system in Zarzita, Fedre, Katoura and Kalif, as a water pumping system in Zarzita and as a desalination system in Kalif, through 3 years operation and utilization, the effect to the livelihood of the villagers are evaluated.

7.1 Cottage industry development by surplus electricity of centralized PV system

7.1.1 Application of PV system to cottage industry

In the summer season, surplus electricity is generated from the centralized 35kW PV system in Zarzita. The objective of a cottage industry is to utilize this surplus electricity during summer season and to increase the villager's income and to improve their livelihood.

7.1.2 Market survey and business selection

In case of new business development, key issues might be what to make, what to sell, how to get materials, how to retain competitiveness and so on. Also, social restrictions must be considered. Proposed ideas were analyzed and handicrafts were selected. Syria has a lot of tourist spots, but lacks attractive souvenirs. There is a big potential market of handicrafts, which target increasing number of tourists. Handicrafts, which can be made by electricity during the summer season and stored as inventory, meet the requirements of this project. In particular, Zarzita can take advantage of its proximity to St. Simeon Castle where many tourists visit. Handicrafts for these tourists have relatively high added value and are suited for concentrated production and storage. In addition, the government of Syria is now promoting tourism industry and has strong interest in technological assistance from other countries. In this area, Japan can make substantial contribution and the expected overall effect is larger than other ideas.

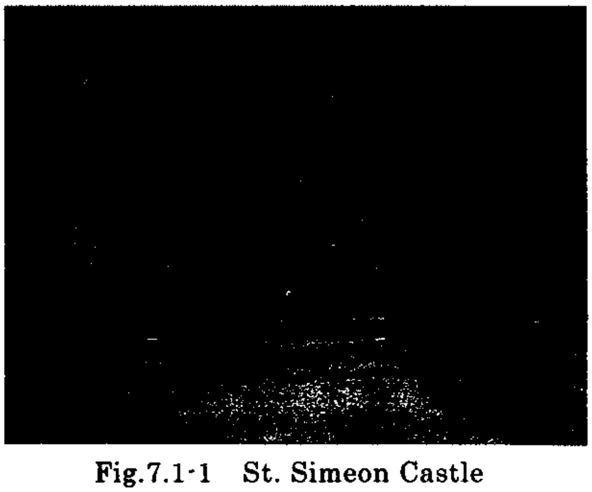


Fig.7.1-1 St. Simeon Castle

7.1.3 Business plan

(1) Conditions for new venture

In Syria, when they would like to sell something at archaeological site, they must apply for permit to the General Directorate of Museums and Antiques in Damascus. This rule applies to the St. Simeon Castle, which is important archaeologically. A committee in the Directorate reviews the application and makes a decision. We can only sell what is approved at designated shop. Therefore, Zarzita villagers must ask the souvenir shop owner at the caste to sell their products.

Owing to the effort of UNDP consultant, the permission was issued in September 1998, and this venture was finally ready for actual execution. This permission stipulates that the seller shall ship the products to the Aleppo Museum where the branch office of the General Directorate is located. The museum, then, ships the products to the order of its three outlets, which are located at Aleppo Museum, St. Simeon Castle, and Aleppo Castle respectively. Also, the permission stipulates 30% of sales proceeds as royalty to the General Directorate, and 10% as sales commission to the retail outlets.

(2) Product line

We decided to produce two products, cloisonné and stone powder molding, as trial. The producing procedure and design of product was studied practically.

①Cloisonné

Cloisonné is common in the Middle East. We can find accessories made by the same technique in many stores in Damascus and Aleppo. Basic method is to paint by glass powder on the surface of pressed base metal (copper) and put it into a furnace. The temperature inside the furnace is around 800℃. Power is used for the electric oven (2kW) of furnace. All the necessary equipment and materials can be purchased in Aleppo. By the later consideration, glass powder was changed to resin powder. According to this change, the furnace temperature was down to 150℃.

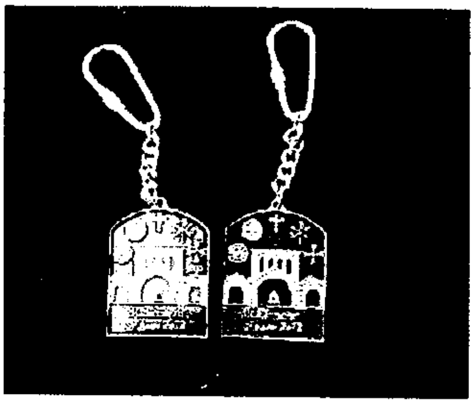


Fig.7.1-2 Key holder made by Cloisonné

②Stone powder product

There are abundant resources of limestone near Zarzita. St. Simeon Castle is a limestone monument built in the Roman Period. It is, therefore, a good idea to create a souvenir by limestone, which will remind the visit to the monument. As it is difficult to process limestone directly, a special method which uses silicon rubber as mold and limestone powder mixed with polyester resin is adopted. The mixture with catalyst is poured into mold to make desired shape. The design work and molds were done in Japan. It would be easy to find this technology in Syria, which would enable other product ideas.

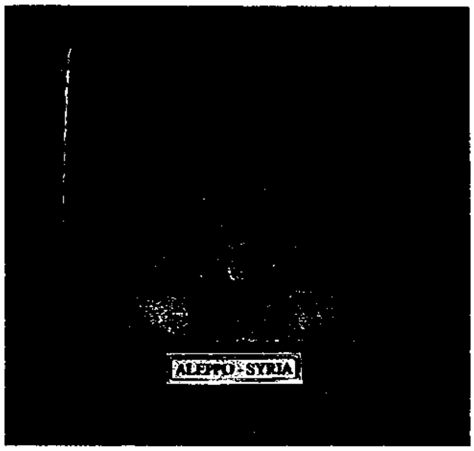


Fig.7.1-3 Ornament made from stone powder

On the key holders, which the villagers produced, test marketing was conducted in November and December 1998 at St. Simeon. Even though there were relatively few tourists, the sales went well. Tourists liked the products despite its relatively high retail price (200SP). About thirty pieces were sold in two weeks. There would have been much more sales, if a display case had been in place. In July 1999, the display case was completed and sales have been increasing since then. The test sales of stone powder products started in March 1999. Sample products were well received by tourists. Its price is set at 300SP, which is also relatively high, but sales are in good shape. In July 1999, special cosmetic box was manufactured to give better appearance.

7.2 Effect of introduction of PV system in villages

7.2.1 Survey of daily activity hours

To survey the difference of daily activities in village before and after system introduction, in 1998 March to April, respondent of Man 54 and Woman 41 in Zarzita, Fedre, Katoura was picked up randomly and made interview survey.

7.2.2 Survey of the other impact for daily livelihood and acceptance by users

This survey was made by visiting about 50% of sampled families out of 105 families in four villages using questionnaire. Respondent are a head of house, his wife, his son and daughter by considering family members.

7.2.3 Survey of changes in related expenditure after the system introduction

- As for the water costs, interview survey was made on 14 families of Zarzita in June 1999, and interview survey was made on Kalif in September 1998.
- As for the costs relating to lighting, interview surveys were made in March 1997 and September 1998.

7.2.4 Survey Result

(1) Changes of time of daily activity by PV electrification

Changes of time of daily activity were surveyed and result is shown in Table 7.2-1. There is no significant difference in time of wake up, breakfast, lunch and dinner but time of go to bed is changed to late 1.2 to 1.5 hours from before system introduction. This is caused by TV, Radio and brightness of lighting.

Table 7.2-1 Change of time of daily activity

		Wake up	Breakfast	Lunch	Dinner	Go to bed
Man	Before	05:15	07:01	12:57	18:44	**21:08**
	After	05:13	07:01	12:57	18:47	**22:31**
Woman	Before	05:23	07:03	12:53	18:37	**20:38**
	After	05:19	07:03	12:53	18:42	**21:49**

(2) Change in life due to the use of electricity

The hours of daily activities were surveyed before and after the introduction of the systems. Large changes were observed as shown below.

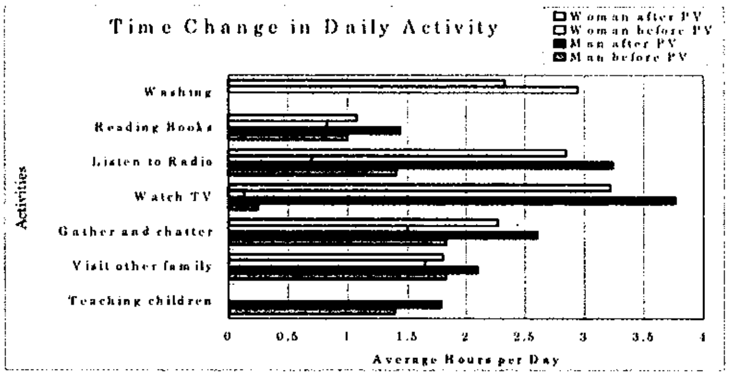


Fig.7.2-1 Change in Hours of Daily Activity

The largest change was the increase in the time of watching TV by about three hours for both men and women. The second largest change was the increase in the time of listening to the radio. These changes indicate that the quantity of information that is received by the residents of the villages has been increasing rapidly. On the other hand, as the lighting of rooms got brighter, the time of reading books and the children's time of studying increased.

7.2.5 Investigation of other effects

(1) Improvement of house environment

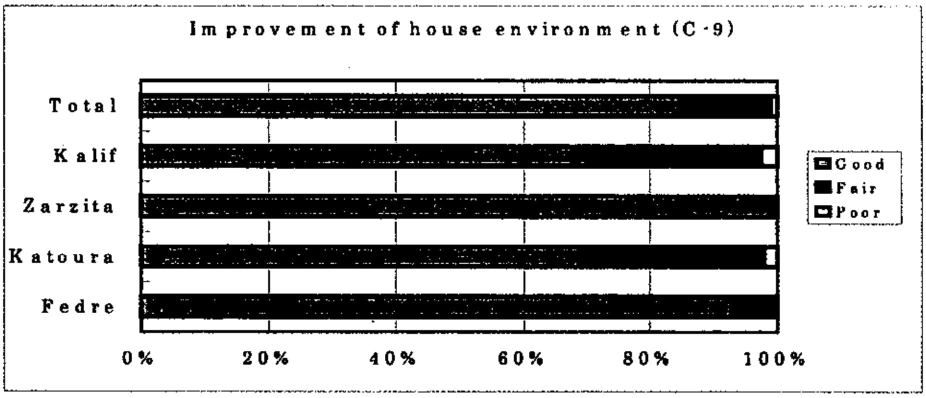


Fig.7.2-2 Improvement of house environment

The switch of lighting from kerosene lamp to fluorescent lamp generates changes. The brightness is better. Women and children do not have to maintain the lamps anymore. Soot is not generated anymore. The residents of all the villages confirmed the positive effects of improving house environment.

(2) Listening and viewing of radio and TV

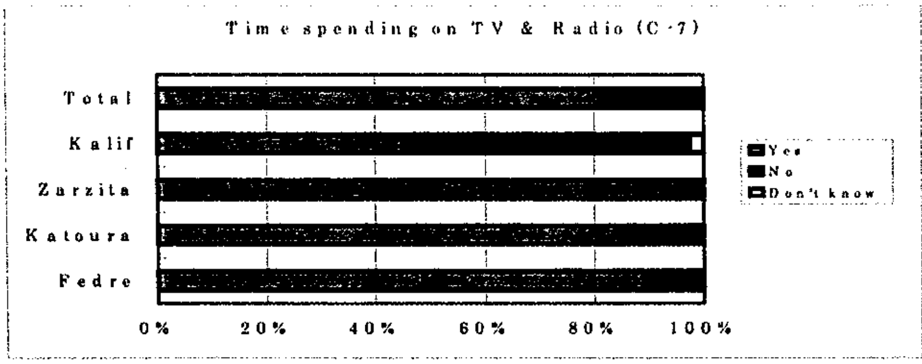


Fig.7.2-3 Effects on TV and Radio

The residents of the respective villages showed satisfaction with listening and viewing of radio and TV, a result of electrification.

(3) Levels of fulfillment of expectations

We examined the findings of the questionnaire surveys from the viewpoint of expectations for power and water supply through electrification. The findings are summarized as follows. Indoor and outdoor lighting has improved safety and convenience. The quantity of information provided by TV and radio has increased significantly. As for the supply of water, the expenditure-reducing effect was very large because the water fee set by the Aleppo Water Authority is lower than the water price of the suppliers.

Table 7.2-2 Expected effect of PV system and degree of realization

System introduced	Expected effects	Degree of realization
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.

(4) Acceptance level of PV systems by the residents

Acceptance level of PV systems as a whole by the residents of the respective four villages was surveyed and rated in three levels; good, fair, poor. The results were as shown below.

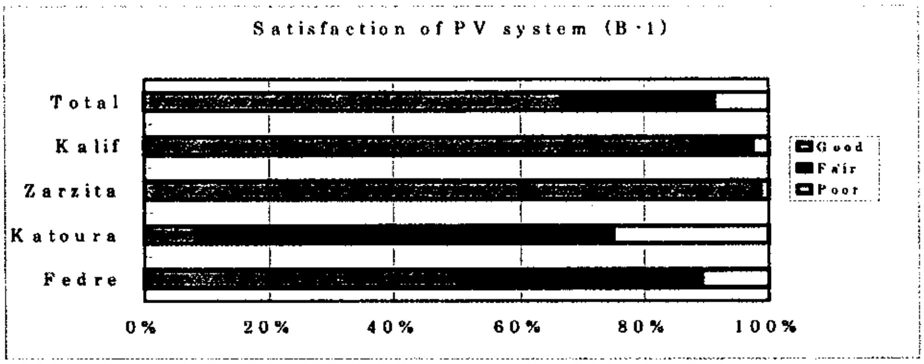


Fig.7.2-4 Satisfaction with PV System

The results indicate that about 70% of the total residents of the four villages are satisfied, and more than 90% of the total residents are satisfied when residents of fair" are included. This means that the systems are contributing to enhancement of the livelihood of the residents, which is the objective of the project.

8 . Economic Analysis of PV System

Economics are mainly examined for " PV systems" and " Planning materials of various PV systems utilization" in this chapter. The outlines of the evaluations are as follows:

8.1 Assumption of system equipment unit price at 2005

The unit price of PV system equipment was assumed as follows for economic analysis.

Table 8.1-1 Assumption of system equipment unit price at 2005

	Life	Present (Reference)	2005	Remarks
PV module	20	4.1(US$/W)	2.2(US$/W)	120W or more
		4.25(US$/W)	2.6(US$/W)	60W
Controller	10	4.81(US$/A)	3.3(US$/A)	12V
		3.92(US$/A)	2.25(US$/A)	24V
Battery	8	0.48(US$/Ah)	0.38(US$/Ah)	
Inverter	10	0.29(US$/W)	0.21(US$/W)	
Other materials	20	5(%) of system price		
Labor	20	〃		

<Source> Renewable Energy Review Issue 2000-2001 Vol3 No.4

8.2 Economic comparison between kerosene lamp/battery-powered TV VS PV systems

Kerosene lamps are normally used for lighting at night in un-electrified houses. The number of such lamps depends on the number of rooms, but usually a fairly large lamp of a fixed type and a small all-night lamp are used. On the premise of the use of lighting and battery-powered TV, all costs of kerosene lighting and battery-powered TV and that of PV system were compared.

8.2.1 Case of kerosene lamp and battery-powered TV

Costs related to kerosene lamp and TV was calculated at an interest rate of 6.5%. The total cost in present value related to the use of lighting and TV over 20 years is determined by multiplying the annual cost (US$118.7) with the coefficient of discounted value (1/capital recovery factor(CRF)) at the interest rate of 6.5%; US$118.7/0.090756 = US$1,307. Consumption of power that is equivalent to the lighting(20W x 1 lamp x 5hr/day + 5W x 1 lamp x 8hr/day)and battery TV(12W x 5hr/day) under the conditions of the above-mentioned assumption is 73 kWh per year. This result means that the household in un-electrified village spends US$118.7 per year or US$ 1,307 over twenty years for kerosene lamp and battery-powered TV.

However, this expense may be considered to be equivalent to the benefits of kerosene lighting and TV watching with car batteries.

8.2.2 Case of introduction of PV system

One of alternative to kerosene lamp and battery-powered TV in un-electrified villages is PV system. Kerosene lamps and a battery-powered TV correspond to an equivalent electric output of 37 W. A specific PV system that can supply this electric output may be 60 W PV module systems. Based on the assumption of Item 8.1, the annual equalized cost related to 60W individual PV systems including in-house wiring under the interest rate of 6.5% was US$32.0. The cost over 20 years in present value was US$353.

8.2.3 Economic comparison between two cases

As all the costs of kerosene lamp and battery-powered TV and that of 60W PV systems were compared here in economics.

(1) Arrangement of both cost

The cost studied is arranged and shown in the following table. Annual cost in the present context is the cost equalized over the useful life at the interest rate of 6.5%.

8.2-1 Costs of two cases (US$)

Case	Annual cost	Cost over 20 years	Remarks
Kerosene lamp Battery TV	118.7	1,307	Coefficient of discounted =11.017
60W PV system	32.0	353	

(2) Comparison of economics

First, the equivalent energy consumption, which provides the basis of comparison, is confirmed. In the case of kerosene lamp and battery TV, 20W x 5hr + 5W x 8hr = 140Wh is used for lighting a day, and 12W x 5hr=60Wh is used for TV a day. Thus a total of 200Wh is used a day. On the other hand, as the utilization factor of 60W PV system is about 10%, energy of 24hr x 0.1 x 60W = 144Wh can be used a day. This energy is almost same as the energy used for lighting and use of TV. If we assume that it is a common practice in un-electrified villages to use kerosene lamps for lighting and car batteries for watching TV, this can be done in any places. Hence the benefit of lighting and battery-powered TV is US$118.7 per year and US$1,307 over

20 years. On the other hand, the benefit of 60W PV systems is US$32.0 per year and US$353 over 20 years. As a result, 60 W PV systems can be an alternative of kerosene lamp and battery-powered TV.

8.3 Proposal of planning materials for PV systems

With regard to the village electrification and pumping/desalination system, which introduced in this project, for preparing materials to make a PV system introduction plan, economic analysis of the respective system and evaluation in comparison with the alternatives was carried out.

8.3.1 Village electrification by PV system

Regarding the centralized PV system, in Zarzita, system scale is 35kW and standard equipment did not apply for the inverter and controller. Based on these, large scale centralized PV system is available from technical aspect. However, it is not feasible from the viewpoint of economics. On Zarzita, this village is unique in a sense that houses are packed in a narrow space for using wells in a relic of an olive oil mill of the Roman period. As there are few similar villages in Syria, the centralized system is out of the scope. Specific capacities considered are as follows:

Individual system	:	60 W, 120 W, 240 W, 360 W, 480 W
Mini-centralized system	:	960 W, 2,040 W, 3,000 W

(1) Assumption of power demands

On the actual records of operation data obtained by the various electrification systems, power demands were assumed for various kinds of electric appliances, which is expected to use. As a result, the capacity factor of the individual systems was estimated to be about 6% in yearly average for the nighttime. Capacity factor of the individual systems for daytime was estimated to be about 7%; use of TV improved it a little. As for the mini-centralized systems, power expected to be used for pumping in daytime, which amounts to about 3%. Thus the annual capacity factor estimated to be improved to 9%.

$$\text{Capacity factor} = \frac{\text{Power generated by the system}}{\text{Rated output (W)} \times 24\text{(hr)} \times \text{Operating days (day)}} \times 100\ (\%)$$

(3) Calculation results of generating costs for PV systems

The costs of the individual and mini-centralized PV systems, which were calculated on the above-mentioned assumptions, are shown in the table below. On battery, the following cases were examined:

a. When conventional overseas batteries for PV system are used and its useful life is assumed to be 5 years.

b. When overseas seal type batteries with guaranteed useful life of 10 years are used.

c. When improved batteries made in Syria are used.

As for the mini-centralized systems, the following two cases were examined:

a. When the average line length from PV system to respective houses is 30 m.

b. When the average line length is 60 m.

Table 8.3-1 Cost of individual PV system

1)Battery : PV use,Life=5years

		60W	120W	240W	360W	480W	Remarks
Module	(US$)	136	262	523	785	1,046	
Controller	(US$)	17	34	67	101	135	
Inverter	(US$)	0	0	0	0	0	
Battery	(US$)	17	35	70	105	139	
Transportation	(US$)	9	17	34	51	68	
Material cost	(US$)	50	50	78	95	152	Enumerated
Labor cost	(US$)	17	17	19	20	25	Enumerated
Total	(US$)	246	414	791	1,156	1,565	
Electric energy	(kWh)	53	105	210	315	420	
Generating cost							
20 Years	($/kWh)	0.540	0.466	0.448	0.438	0.444	No price increase
30 Years	($/kWh)	0.483	0.419	0.404	0.396	0.400	No price increase
Inflation =3%	($/kWh)	0.576	0.499	0.481	0.471	0.477	

2) Battery : Seal,Life=10Years

		60W	120W	240W	360W	480W	Remarks
Module	(US$)	136	262	523	785	1,046	
Controller	(US$)	17	34	67	101	135	
Inverter	(US$)	0	0	0	0	0	
Battery	(US$)	25	80	160	240	321	
Transportation	(US$)	9	20	39	57	77	
Material cost	(US$)	50	59	78	95	152	Enumerated
Labor cost	(US$)	17	18	19	20	25	Enumerated
Total	(US$)	253	472	886	1,299	1,756	
Electric energy	(kWh)	53	105	210	315	420	
Generating cost							
20 Years	($/kWh)	0.640	0.507	0.480	0.470	0.476	No price increase
30 Years	($/kWh)	0.583	0.460	0.517	0.428	0.433	No price increase
Inflation =3%	($/kWh)	0.702	0.540	0.511	0.501	0.507	

3) Battery : Made in Syria,Life=3Years

		60W	120W	240W	360W	480W	Remarks
Module	(US$)	136	262	523	785	1,046	
Controller	(US$)	17	34	67	101	135	
Inverter	(US$)	0	0	0	0	0	
Battery	(US$)	25	50	100	151	201	
Transportation	(US$)	9	16	32	47	63	
Material cost	(US$)	50	59	78	95	152	Enumerated
Labor cost	(US$)	17	18	19	20	25	Enumerated
Total	(US$)	253	439	820	1,199	1,622	
Electric energy	(kWh)	53	105	210	315	420	
Generating cost							
20 Years	($/kWh)	0.640	0.575	0.547	0.538	0.543	No price increase
30 Years	($/kWh)	0.583	0.527	0.504	0.495	0.602	No price increase
Inflation =3%	($/kWh)	0.702	0.635	0.607	0.596	0.500	

Table 8.3-2 Cost of mini centralized PV system

1) Battery : PV use,Life=5Years

	Mean distance=30m			Mean distance=60m			Remarks
	960W	2,040W	3,000W	960W	2,040W	3,000W	
Module (US$)	2,093	4,447	6,540	2,093	4,447	6,540	
Controller (US$)	102	218	320	102	218	320	
Inverter (US$)	161	343	504	161	343	504	
Battery (US$)	279	592	871	279	592	871	
Transportation (US$)	139	295	435	144	304	447	
Material cost (US$)	681	1,366	2,048	1,105	2,219	3,328	Enumerated
Labor cost (US$)	76	154	232	76	154	232	Enumerated
Total (US$)	3,532	7,415	10,950	3,960	8,277	12,243	
Electric energy (kWh)	841	1,787	2,628	841	1,787	2,628	
Generating cost							
20 Years ($/kWh)	0.491	0.486	0.488	0.543	0.535	0.537	No inflation
30 Years ($/kWh)	0.441	0.437	0.438	0.485	0.479	0.481	No inflation
Inflation =3% ($/kWh)	0.526	0.520	0.522	0.579	0.571	0.573	

2)Battery : Seal,Life=10Years

	Mean distance=30m			Mean distance=60m			Remarks
	960W	2,040W	3,000W	960W	2,040W	3,000W	
Module (US$)	2,093	4,447	6,540	2,093	4,447	6,540	
Controller (US$)	102	218	320	102	218	320	
Inverter (US$)	161	343	504	161	343	504	
Battery (US$)	641	1,363	2,004	641	1,363	2,004	
Transportation (US$)	157	334	491	157	342	504	
Material cost (US$)	681	1,366	2,048	1,105	2,219	3,328	Enumerated
Labor cost (US$)	76	154	232	76	154	232	Enumerated
Total (US$)	3,912	5,224	12,139	4,335	9,085	13,432	
Electric energy (kWh)	841	1,787	2,628	841	1,787	2,682	
Generating cost							
20 Years ($/kWh)	0.523	0.518	0.520	0.572	0.567	0.570	No inflation
30 Years ($/kWh)	0.473	0.469	0.471	0.515	0.511	0.513	No inflation
Inflation =3% ($/kWh)	0.556	0.551	0.553	0.606	0.601	0.604	

3) Battery : Made in Syria,Life=3Years

	Mean distance=30m			Mean distance=60m			Remarks
	960W	2,040W	3,000W	960W	2,040W	3,000W	
Module (US$)	2,093	4,447	6,540	2,093	4,447	6,540	
Controller (US$)	102	218	320	102	218	320	
Inverter (US$)	161	343	504	161	343	504	
Battery (US$)	402	854	1,256	402	854	1,256	
Transportation (US$)	129	274	404	129	283	416	
Material cost (US$)	681	1,366	2,048	1,105	2,219	3,328	Enumerated
Labor cost (US$)	76	154	232	76	154	232	Enumerated
Total (US$)	3,645	7,655	11,303	4,068	8,517	12,596	
Electric energy (kWh)	841	1,787	2,628	841	1,787	2,628	
Generating cost							
20 Years ($/kWh)	0.591	0.586	0.588	0.640	0.635	0.637	No inflation
30 Years ($/kWh)	0.541	0.537	0.648	0.582	0.578	0.581	No inflation
Inflation =3% ($/kWh)	0.651	0.646	0.538	0.701	0.696	0.699	

8.3.2 Comparison of generating cost between PV system and grid extension

An alternative method of PV system village electrification, grid extension is considered. In here, based on the construction costs and other data of PEDEEE, generating cost for grid extension was calculated and economic comparison was made with PV system. Detail assumption will be described in the Main report.

(1) Generating cost for grid extension

Based on the construction and material costs of PEDEEE, distance of grid extension, number of houses, capacity of electric appliances and load factor is as a parameter, the generating cost of grid extension was calculated and compared with that of PV system. The result is indicated in Table 8.3-3 and 8.3-4.

(2) Comparison of generating cost of grid extension and that of PV system

The generating cost of PV system is about US$0.6/kWh as calculated above. On the other hand, the generating cost of grid extension was calculated using a parameter of length of grid extension, number of houses and load factor etc. Also, the above-mentioned assumption is taken into account. From a viewpoint of US$0.6/kWh, PV system and grid extension was compared and result is shown in Table 8.3-12 and 8.3-13.

a. Even when the distance from the existing grid line to the village is close, if the number of households in the village is small, the generating cost by grid extension will be expensive. If the distance gets longer, the generating cost will increase in proportion to the distance.

b. When the distance to the village is 5 km, if the number of customer households is about 40 and their power demands are not large, the generating cost by grid extension cannot be competitive to that of PV system.

c. When the load factor of the grid lines gets larger, in other words, when the power demands of the respective customers get larger, the generating cost by grid extension will naturally decrease. However, the load factor is low in case of power for housing and it is rare that the load factor exceeds 30 %. As a result, in electrification of un-electrified villages, if the number of households to be electrified is not large, or if the power peak and power demands of the respective customers are not large, generating cost by grid extension will be high and cannot be economical.

d. When the number of households in the village is small and the distance from the existing grid lines to the village is long, introduction of PV system is more advantageous than grid extension.

Table 8.3-3 Generating cost by grid extension

(shaded) Advantage for PV system

(1) Demand 100W

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(2) Demand 300W

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(3) Demand 500W

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	0.56	[illegible]	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	0.52	[illegible]	[illegible]	[illegible]	[illegible]
50	0.44	[illegible]	[illegible]	[illegible]	[illegible]
60	0.39	[illegible]	[illegible]	[illegible]	[illegible]
70	0.37	0.57	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	0.57	[illegible]	[illegible]	[illegible]	[illegible]
50	0.48	[illegible]	[illegible]	[illegible]	[illegible]
60	0.43	[illegible]	[illegible]	[illegible]	[illegible]
70	0.39	[illegible]	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	0.45	[illegible]	[illegible]	[illegible]	[illegible]
40	0.36	0.60	[illegible]	[illegible]	[illegible]
50	0.31	0.50	[illegible]	[illegible]	[illegible]
60	0.28	0.44	0.59	[illegible]	[illegible]
70	0.27	0.40	0.53	[illegible]	[illegible]

Table 8.3-4 Generating cost by grid extension

(shaded) Advantage for PV system

(1) Life = 20 years, Increase = 0%

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	10.13	19.39	28.65	37.91	47.17
6	5.18	9.81	14.44	19.07	23.70
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	2.71	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(2) Life = 20 years, Increase = 3%

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(3) Life = 30 years, Increase = 0%

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	0.60	[illegible]	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	0.52	[illegible]	[illegible]	[illegible]	[illegible]
50	0.44	[illegible]	[illegible]	[illegible]	[illegible]
60	0.39	[illegible]	[illegible]	[illegible]	[illegible]
70	0.37	0.57	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	0.54	[illegible]	[illegible]	[illegible]	[illegible]
50	0.46	[illegible]	[illegible]	[illegible]	[illegible]
60	0.41	[illegible]	[illegible]	[illegible]	[illegible]
70	0.39	0.60	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	0.56	[illegible]	[illegible]	[illegible]	[illegible]
40	0.46	[illegible]	[illegible]	[illegible]	[illegible]
50	0.39	[illegible]	[illegible]	[illegible]	[illegible]
60	0.35	0.55	[illegible]	[illegible]	[illegible]
70	0.33	0.50	[illegible]	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	0.45	[illegible]	[illegible]	[illegible]	[illegible]
40	0.36	0.60	[illegible]	[illegible]	[illegible]
50	0.31	0.50	[illegible]	[illegible]	[illegible]
60	0.28	0.44	0.59	[illegible]	[illegible]
70	0.27	0.40	0.53	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	0.47	[illegible]	[illegible]	[illegible]	[illegible]
40	0.38	[illegible]	[illegible]	[illegible]	[illegible]
50	0.33	0.52	[illegible]	[illegible]	[illegible]
60	0.29	0.46	[illegible]	[illegible]	[illegible]
70	0.28	0.42	0.56	[illegible]	[illegible]

Load factor / year: No. of house	Distance [km] 5	10	15	20	25
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	0.40	[illegible]	[illegible]	[illegible]	[illegible]
40	0.32	0.53	[illegible]	[illegible]	[illegible]
50	0.28	0.44	0.44	[illegible]	[illegible]
60	0.25	0.39	0.39	[illegible]	[illegible]
70	0.24	0.36	0.36	0.59	[illegible]

d. When the number of households in the village is small and the distance from the existing grid lines to the village is long, introduction of PV system is more advantageous than grid extension.

Table 8.3-3 Generating cost by grid extension

☐ Advantage for PV system

(1) Demand 100W

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	50.45	96.72	143.01	189.31	235.60
6	25.67	48.82	71.97	95.11	118.26
9	17.46	32.85	48.28	63.71	79.14
12	13.30	24.87	36.44	48.02	59.59
15	10.82	20.08	29.34	38.60	47.85
30	5.87	10.50	15.13	19.76	24.39
40	4.63	8.10	11.58	15.05	18.52
50	3.89	6.67	9.44	12.22	15.00
60	3.39	5.71	8.02	10.34	12.65
70	3.04	5.02	7.01	8.99	10.98

(2) Demand 300W

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	16.85	32.38	47.71	63.14	78.57
6	8.60	16.31	24.03	31.74	39.46
9	5.85	10.99	16.13	21.28	26.12
12	4.47	8.33	12.19	16.04	19.90
15	3.65	6.73	9.82	12.90	15.99
30	22.00	3.54	5.08	6.62	8.17
40	1.58	2.74	3.90	5.50	6.21
50	1.33	2.26	3.19	4.11	5.04
60	1.17	1.95	2.72	3.49	4.26
70	1.06	1.72	2.38	3.04	3.70

(3) Demand 500W

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	10.13	19.39	28.65	37.91	47.17
6	5.18	9.81	14.44	19.07	23.70
9	3.53	6.62	9.70	12.79	15.88
12	2.71	5.02	7.33	9.65	11.96
15	2.21	4.06	5.91	7.77	9.62
30	1.22	2.15	3.07	4.00	4.92
40	0.98	1.67	2.37	3.06	3.75
50	0.83	1.38	1.94	2.49	3.05
60	0.73	1.19	1.65	2.12	2.58
70	0.68	1.08	1.48	1.87	2.27

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	25.24	48.39	71.54	94.68	117.83
6	12.87	24.41	36.01	47.58	59.16
9	8.74	16.46	24.17	31.89	39.60
12	6.68	12.46	18.25	24.04	29.82
15	5.44	10.07	14.70	19.33	23.96
30	2.96	5.28	7.59	9.91	12.22
40	2.34	4.08	5.82	7.55	9.29
50	1.97	3.36	4.75	6.14	7.53
60	1.73	2.88	4.01	5.20	6.36
70	1.55	2.54	3.53	4.52	5.52

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	8.45	16.17	23.88	31.60	39.31
6	4.33	8.18	12.04	15.90	19.76
9	2.95	5.52	8.10	10.67	13.24
12	2.26	4.19	6.12	8.05	9.98
15	1.85	3.39	4.94	6.48	8.02
30	1.03	1.80	2.57	3.34	4.11
40	0.82	1.40	1.98	2.56	3.13
50	0.70	1.16	1.62	2.08	2.55
60	0.62	1.00	1.39	1.77	2.16
70	0.56	0.89	1.22	1.55	1.88

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	5.09	9.72	14.35	18.98	23.61
6	2.62	4.93	7.25	9.56	11.88
9	1.79	3.34	4.88	6.42	7.97
12	1.38	2.54	3.70	4.85	6.01
15	1.13	2.06	2.99	3.91	4.84
30	0.64	1.10	1.56	2.03	2.49
40	0.52	0.86	1.21	1.56	1.91
50	0.44	0.72	1.00	1.28	1.55
60	0.39	0.62	0.86	1.09	1.32
70	0.37	0.57	0.77	0.97	1.16

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	16.85	32.28	47.71	63.14	78.57
6	8.60	16.31	24.03	31.74	39.46
9	5.85	10.99	16.13	21.28	26.42
12	4.47	8.33	12.19	16.04	19.90
15	3.65	6.73	9.82	12.90	15.99
30	2.00	3.54	5.08	6.62	8.17
40	1.58	2.74	3.90	5.05	6.21
50	1.33	2.26	3.19	4.11	5.04
60	1.17	1.94	2.71	3.48	4.26
70	1.05	1.71	2.37	3.04	3.70

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	5.65	10.80	15.94	21.09	26.23
6	2.90	5.48	8.05	10.62	13.19
9	1.99	3.70	5.42	7.13	8.85
12	1.53	2.81	4.10	5.39	6.67
15	1.25	2.28	3.31	4.34	5.37
30	0.70	1.22	1.73	2.25	2.76
40	0.57	0.95	1.34	1.72	2.11
50	0.48	0.79	1.10	1.41	1.72
60	0.45	0.69	0.94	1.20	1.46
70	0.39	0.61	0.83	1.05	1.27

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	3.42	6.50	9.59	12.67	15.76
6	1.77	3.31	4.85	6.39	7.94
9	1.22	2.24	3.27	4.30	5.33
12	0.94	1.71	2.48	3.25	4.03
15	0.78	1.39	2.01	2.63	3.24
30	0.45	0.75	1.06	1.37	1.68
40	0.36	0.60	0.83	1.06	1.29
50	0.31	0.50	0.68	0.87	1.05
60	0.28	0.44	0.59	0.74	0.90
70	0.27	0.40	0.53	0.66	0.80

Table 8.3-4 Generating cost by grid extension

☐ Advantage for PV system

(1) Life = 20 years, Increase = 0 %

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	10.13	19.39	28.65	37.91	47.17
6	5.18	9.81	14.44	19.07	23.70
9	3.53	6.62	9.70	12.79	15.88
12	2.71	5.02	7.33	9.65	11.96
15	2.21	4.06	5.91	7.77	9.62
30	1.22	2.15	3.07	4.00	4.92
40	0.98	1.67	2.37	3.06	3.75
50	0.83	1.38	1.94	2.49	3.05
60	0.73	1.19	1.65	2.12	2.58
70	0.68	1.08	1.48	1.87	2.27

(2) Life = 20 years, Increase = 3%

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	10.68	20.44	30.21	39.97	49.73
6	5.46	10.34	15.22	20.10	24.99
9	3.72	6.97	10.23	13.48	16.74
12	2.85	5.29	7.73	10.17	12.61
15	2.33	4.28	6.23	8.19	10.14
30	1.28	2.26	3.24	4.21	5.19
40	1.03	1.76	2.49	3.22	3.96
50	0.87	1.46	2.04	2.63	3.21
60	0.76	1.25	1.74	2.23	2.72
70	0.72	1.14	1.56	1.97	2.39

(3) Life = 30 years, Increase = 0

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	8.84	16.92	24.99	33.06	41.13
6	4.53	8.56	12.60	16.63	20.67
9	3.09	5.78	8.47	11.16	13.85
12	2.37	4.38	6.40	8.42	10.44
15	1.93	3.55	5.16	6.78	8.39
30	1.07	1.88	2.69	3.49	4.30
40	0.86	1.46	2.07	2.68	3.28
50	0.73	1.21	1.70	2.18	2.67
60	0.64	1.05	1.45	1.85	2.26
70	0.60	0.95	1.30	1.64	1.99

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	5.09	9.72	14.35	18.98	23.61
6	2.62	4.93	7.25	9.56	11.88
9	1.79	3.34	4.88	6.42	7.97
12	1.38	2.54	3.70	4.85	6.01
15	1.13	2.06	2.99	3.91	4.81
30	0.64	1.10	1.56	2.03	2.49
40	0.52	0.86	1.21	1.56	1.91
50	0.44	0.72	1.00	1.28	1.55
60	0.39	0.62	0.86	1.09	1.32
70	0.37	0.57	0.77	0.97	1.16

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	5.37	10.25	15.13	20.01	24.90
6	2.76	5.20	7.64	10.08	12.52
9	1.89	3.52	5.14	6.77	8.40
12	1.45	2.67	3.89	5.11	6.34
15	1.19	2.17	3.15	4.12	5.10
30	0.67	1.16	1.65	2.13	2.62
40	0.54	0.91	1.27	1.64	2.01
50	0.46	0.76	1.05	1.34	1.64
60	0.41	0.66	0.90	1.14	1.39
70	0.39	0.60	0.81	1.02	1.22

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	4.45	8.49	12.52	16.56	20.60
6	2.29	4.31	6.33	8.35	10.36
9	1.57	2.92	4.26	5.61	6.95
12	1.21	2.22	3.23	4.24	5.25
15	1.00	1.80	2.61	3.42	4.23
30	0.56	0.97	1.37	1.78	2.18
40	0.46	0.76	1.06	1.37	1.67
50	0.39	0.64	0.88	1.12	1.36
60	0.35	0.55	0.75	0.96	1.16
70	0.33	0.50	0.68	0.85	1.02

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	3.42	6.50	9.59	12.67	15.76
6	1.77	3.31	4.85	6.39	7.94
9	1.22	2.24	3.27	4.30	5.33
12	0.94	1.71	2.48	3.25	4.03
15	0.78	1.39	2.01	2.63	3.24
30	0.45	0.75	1.06	1.37	1.68
40	0.36	0.60	0.83	1.06	1.29
50	0.31	0.50	0.68	0.87	1.05
60	0.28	0.44	0.59	0.74	0.90
70	0.27	0.40	0.53	0.66	0.80

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	3.60	6.85	10.11	13.36	16.62
6	1.86	3.49	5.11	6.74	8.37
9	1.28	2.36	3.45	4.53	5.62
12	0.99	1.80	2.62	3.43	4.24
15	0.81	1.47	2.12	2.77	3.42
30	0.47	0.79	1.12	1.44	1.77
40	0.38	0.62	0.87	1.11	1.36
50	0.33	0.52	0.72	0.91	1.11
60	0.29	0.46	0.62	0.78	0.94
70	0.28	0.42	0.56	0.70	0.84

Load factor / Year	Distance [km]				
	5	10	15	20	25
3	2.99	5.68	8.37	11.06	13.75
6	1.55	2.89	4.24	5.58	6.93
9	1.07	1.96	2.86	3.76	4.66
12	0.83	1.50	2.17	2.85	3.52
15	0.68	1.22	1.76	2.30	2.84
30	0.40	0.66	0.93	1.20	1.47
40	0.32	0.53	0.73	0.93	1.13
50	0.28	0.41	0.44	0.77	0.93
60	0.25	0.39	0.39	0.66	0.79
70	0.24	0.36	0.36	0.59	0.70

8.3.3 Comparison of generating cost between PV systems and diesel generators

Diesel generator is commonly considered to be an alternative power source to PV system in rural areas. The minimal capacity of diesel generators available in the local market is 5kW. Thus, 5kW diesel generator was compared with PV systems.

(1) Assumptions of diesel generator to calculate the generating cost

Supply of electricity from the generator to each household is assumed to be by distribution line of which construction cost is set at US$12,000/km. The mean distance between the generator and the household is set at 50m. Cost of lead-in line is set at US$20 /household. The useful life of the distribution line is set at 20 years. This also applies when the calculation period is 30 years. The distribution loss is assumed at 8%, which is the distribution loss of the grid extension.

(2) Generating costs and comparison with PV system

The generating cost of diesel generator varies as shown below with the parameters, namely, number of houses, average consumption and annual load factor. Area of ■ is the advantage for PV systems.

Table 8.3-7 Generating costs of diesel generator

(1) Useful life: 20 years Interest rate: 6.5% Inflation: 0% (Unit :US$/kWh)

Load	Load Factor	Energy (kWh/household・year)	Number of households supplied with electricity					
			3	6	9	12	15	18
100 W	10%	87.6	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	20%	175.2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
200 W	10%	175.2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	20%	350.4	[redacted]	[redacted]	0.45	0.40	0.36	0.34
300 W	10%	262.8	[redacted]	[redacted]	0.58	0.51	0.46	0.43
	20%	525.6	[redacted]	0.40	0.32	0.29	0.26	0.25
500 W	10%	438.0	[redacted]	0.47	0.38	0.33	0.30	0.27
	20%	876.0	0.41	0.27	0.22	0.20	0.18	0.17

(2) Useful life: 20 years Interest rate: 6.5% Inflation: 3% (Unit :US$/kWh)

Load	Load Factor	Energy (kWh/household・year)	Number of households supplied with electricity					
			3	6	9	12	15	18
100 W	10%	87.6	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	20%	175.2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
200 W	10%	175.2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	20%	350.4	[redacted]	[redacted]	0.50	0.43	0.40	0.37
300 W	10%	262.8	[redacted]	[redacted]	0.64	0.55	0.50	0.46
	20%	525.6	[redacted]	0.45	0.36	0.32	0.29	0.27
500 W	10%	438.0	[redacted]	0.52	0.42	0.36	0.33	0.31
	20%	876.0	0.46	0.30	0.25	0.22	0.21	0.20

(3) Useful life: 30 years Interest rate: 6.5 %, Inflation: 0 %

Table is the same as Table (1).

8.3.3 Comparison of generating cost between PV systems and diesel generators

Diesel generator is commonly considered to be an alternative power source to PV system in rural areas. The minimal capacity of diesel generators available in the local market is 5kW. Thus, 5kW diesel generator was compared with PV systems.

(1) Assumptions of diesel generator to calculate the generating cost

Supply of electricity from the generator to each household is assumed to be by distribution line of which construction cost is set at US$12,000/km. The mean distance between the generator and the household is set at 50m. Cost of lead-in line is set at US$20 /household. The useful life of the distribution line is set at 20 years. This also applies when the calculation period is 30 years. The distribution loss is assumed at 8%, which is the distribution loss of the grid extension.

(2) Generating costs and comparison with PV system

The generating cost of diesel generator varies as shown below with the parameters, namely, number of houses, average consumption and annual load factor. Area of [ ] is the advantage for PV systems.

Table 8.3-7 Generating costs of diesel generator

(1) Useful life: 20 years Interest rate: 6.5% Inflation: 0% (Unit :US$/kWh)

Load	Load Factor	Energy (kWh/household · year)	Number of households supplied with electricity					
			3	6	9	12	15	18
100 W	10%	87.6	**3.48**	**2.08**	**1.62**	**1.39**	**1.25**	**1.15**
	20%	175.2	**1.77**	**1.07**	**0.84**	**0.73**	**0.66**	**0.61**
200 W	10%	175.2	**1.77**	**1.07**	**0.84**	**0.73**	**0.66**	**0.61**
	20%	350.4	**0.92**	**0.57**	0.45	0.40	0.36	0.34
300 W	10%	262.8	**1.20**	**0.74**	0.58	0.51	0.46	0.43
	20%	525.6	**0.63**	0.40	0.32	0.29	0.26	0.25
500 W	10%	438.0	**0.75**	0.47	0.38	0.33	0.30	0.27
	20%	876.0	0.41	0.27	0.22	0.20	0.18	0.17

(2) Useful life: 20 years Interest rate: 6.5% Inflation: 3% (Unit :US$/kWh)

Load	Load Factor	Energy (kWh/household · year)	Number of households supplied with electricity					
			3	6	9	12	15	18
100 W	10%	87.6	**3.82**	**2.26**	**1.74**	**1.48**	**1.33**	**1.22**
	20%	175.2	**1.95**	**1.17**	**0.91**	**0.78**	**0.71**	**0.65**
200 W	10%	175.2	**1.95**	**1.17**	**0.91**	**0.78**	**0.71**	**0.65**
	20%	350.4	**1.02**	**0.63**	0.50	0.43	0.40	0.37
300 W	10%	262.8	**1.33**	**0.81**	0.64	0.55	0.50	0.46
	20%	525.6	**0.71**	0.45	0.36	0.32	0.29	0.27
500 W	10%	438.0	**0.83**	0.52	0.42	0.36	0.33	0.31
	20%	876.0	0.46	0.30	0.25	0.22	0.21	0.20

(3) Useful life: 30 years Interest rate: 6.5 %, Inflation: 0 %

Table is the same as Table (1).