Chapter 7
Effect of Livelihood Improvement
by PV systems Introduction

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The effect of the introduction of cottage industry on the improvement of a livelihood in Zarzita and the effects of 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 are evaluated through three years operation in this chapter.

7.1 Cottage industry development by surplus electricity

7.1.1 Application of PV system to cottage industry

In this JICA project, one of its main objectives is to develop a cottage industry at Zarzita where the large-scale 35kW system is installed. Utilization of surplus electricity during the summer season is the underlying idea for cottage industry development. PV system is designed to produce enough electricity even during the winter season, when insolation is limited. In the summer season, there is a significant amount of surplus electricity, which can be better utilized if a feasible cottage industry is developed. The villagers can benefit from increased revenue from the cottage industry.

7.1.2 Stages of cottage industry development

(1) Coordination committee

The coordination committee, which comprises the Ministry of Social and Work Affairs, the Ministry of Industry, the Aleppo Local Authority, the Chamber of Commerce, the Handicraft Union and others was established at the beginning.

(2) Establishment of project team

Another important element was to have a committed group, which was organized by active young people. The effort to create a new venture requires long time devotion, patience and flexible thinking. For that purpose, a young and active entrepreneur who does not hold on to old traditions is necessary. We needed to find out this type of young man in Zarzita and let him organize a group to develop a cottage industry. At the same time, the villagers should recognize this group and provide necessary support. Frequent technical workshops were held and core members who showed strong commitment were selected as project team members.

(3) Joint work with UNDP

It is necessary to have an expert who can speak Arabic and give the villagers guidance and consultation until they can fully understand how to run the venture. Based on our experience so far, the Japanese expert will have difficulty in fully dealing with the villagers because of language problem and limited time available.

After a series of discussions between JICA and UNDP, it was agreed that UNDP provides a budget to hire an expert and to purchase equipment to help the Japanese expert achieve the goal of cottage industry development. UNDP consultant joined the JICA team in July 1998 and started his work to materialize the business plan, which was developed by the JICA consultant.

7.1.3 Market survey and business selection

(1) Preliminary analysis

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. We analyzed proposed ideas and drew conclusions as follows.

(2) Sewing

Some of the villagers have worked in sewing workshops so that they are quite likely to consider sewing work at home after electrification. It might be expected that large apparel factories will subcontract small sewing workshops in Zarzita. But even in Dartazze, there are no such subcontractors. At the same time it has to be considered that work volume would be dependent on available electricity, which is not stable. Under these circumstances, it would be difficult to do sewing work to the order of clients.

(3) Dairy products

Processing dairy products such as yogurt or cheese is a promising idea because Syrian people consume a lot of dairy products. In the summer season, they have difficulty to preserve dairy products, which means that there is strong demand for specially processed diary products, which can be stored during the summer season. In the Inception Report, cheese processing was mentioned, but it was found afterwards that expected income would be small because of limited market and low food price. Also, a large refrigerator may be needed to keep raw materials and processed products. These conditions will require a large amount of initial investment.

(4) Handicrafts

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 using 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 Syrian government 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.

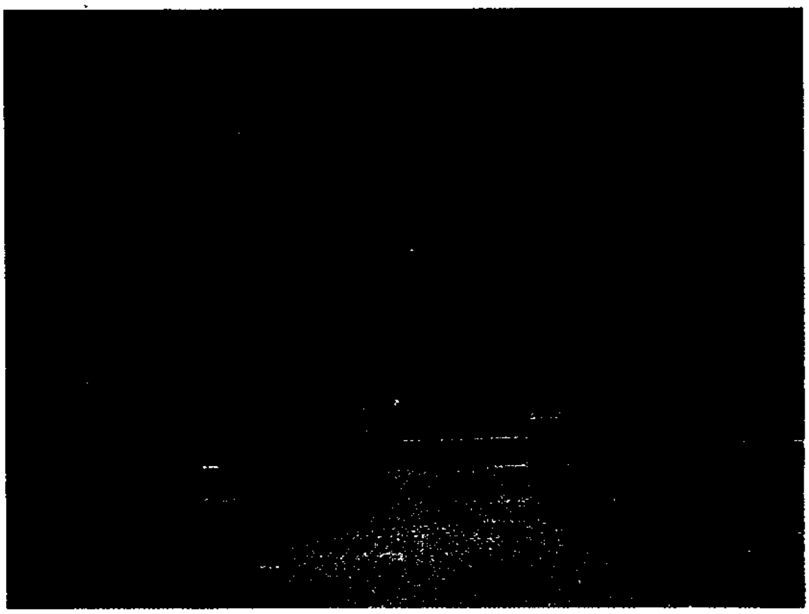


Fig.7.1-1 St. Simeon Castle

7.1.4 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 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. Zarzita villagers, therefore, 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. Cloisonné was thought to be possible by villagers because of its simple process, which requires coloring onto pressed base metal and baking. The villagers were expected to learn the technique of coloring and baking. Stone powder molding was also thought to be possible, because they only needed to process materials and to put them into molds.

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℃. Electricity is used for the electric heater (2kW) of furnace. All the necessary equipment and materials can be purchased in Aleppo. It was understood that we needed to make a good design to match the historical value of St. Simeon Castle.

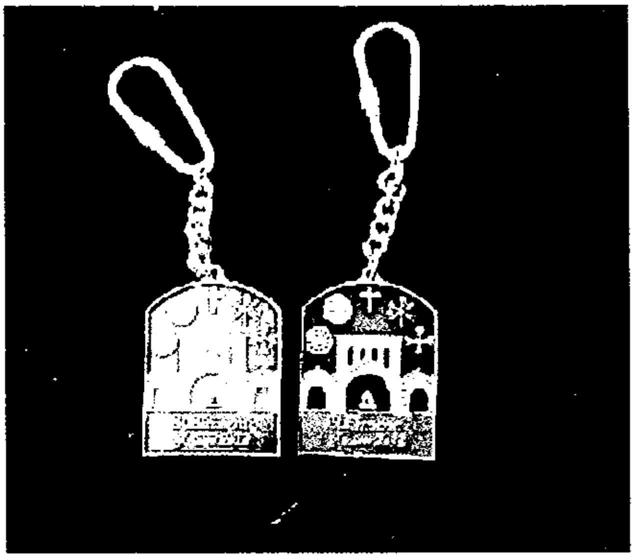


Fig.7.1-2 Key holder made by Cloisonné

②Stone powder product

There are abundant resources of limestone near Zarzita. The 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.

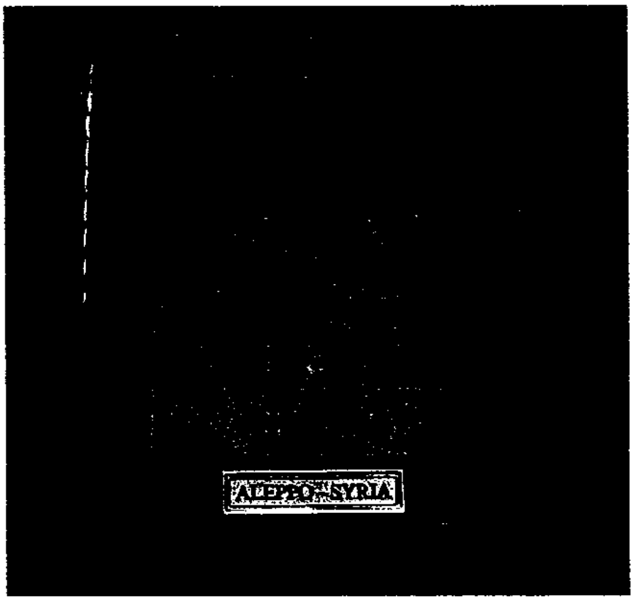


Fig.7.1-3 Ornament made from stone powder

(3) Financial forecast

Key holders made by local villagers were put on test sales from November to December 1998 at the souvenir shop in the St. Simeon Castle. Despite the limited number of tourists during that season, sales volume was better than expected. Quite a number of tourists bought our products, even though the price was 200 SP, which is relatively high, and display box was not ready yet.

Also the test sales of the ornament made from stone powder ended up with good results. Based on these test marketing, we evaluated the sales forecast and profitability of both products.

①Cloisonné

Table 7.1-1 Cost breakdown of cloisonné

Items	Cost (SP)	Ratio (%)
Metal base, Plating	60	30.0
Pigment, Chain	5	2.5
Material cost	**65**	**32.5**
Royalty, Commission	80	40.0
Labor	15	7.5
Administration	10	5.0
Total	170	**85.0**
Retail price	**200**	**100**
Gross margin	30	15.0

②Stone powder

Table 7.1-2 Cost breakdown of stone powder product

Items	Cost (SP)	Ratio (%)
Resin	5	1.7
Wood, Decoration	50	16.7
Material cost	**55**	**18.3**
Commission, Royalty	120	40.0
Labor	25	8.3
Administration	10	3.3
Total cost	**210**	**70.0**
Retail price	**300**	**100**
Gross margin	90	30.0

Thus, the profitability is higher than cloisonné product because its material cost is significantly low.

Sample production of key holders started in mid 1998 and test marketing was conducted in November and December 1998 at St. Simeon Castle. 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 the 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 the sales are in good shape. In July 1999, special cosmetic box was manufactured to give better appearance.

Based on our revised sales forecast, a consolidated financial forecast was formulated as follows. In this forecast, it is assumed that the annual sales volume would reach 4,000 pieces on cloisonné and 3,000 pieces on stone powder products respectively.

Table 7.1-3 Annual sales and profits (Unit : SP)

		Unit price	Volume	Amount	Remarks
Sales	Cloisonné	200	4,000	800,000	
	Stone	300	3,000	900,000	
	Total			1,700,000	
Labor	Cloisonné	(15)	4,000	60,000	
	Stone	(25)	3,000	75,000	
	Total			135,000	
Gross Margin	Cloisonné	(30)	4,000	120,000	
	Stone	(90)	3,000	270,000	
	Total			390,000	

This profit, 390,000 SP, is almost equal to the wages earned by male workers for 1,300 man-day construction works in the Aleppo area. At the same time, it should be mentioned that 135,000 SP are to be paid to the Zarzita people as labor charge. Thus, the cottage industry business would provide significant amount of income to the village as a whole.

7.1.5 Construction of workshop

Until 1998, as a temporary measure, a classroom of elementary school was used as workshop. It had been well recognized that it would be necessary to have a premise for production and storage when production was in full operation. After investigating several ideas regarding the new premise, it was agreed among the people concerned that a new workshop would be constructed by using the UNDP budget next to the PV power station. This workshop has two production rooms, each for cloisonn and stone powder, an office space and storage room which keeps materials and finished products. The workshop was completed in December 1998 and handed over to SSRC.

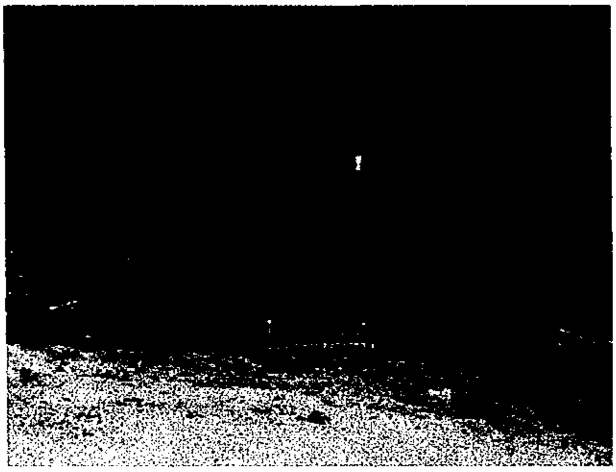


Fig.7.1-4 Front view of workshop

7.1.6 Management structure

Based on these changes in surrounding conditions, SSRC agreed to undertake some of key management tasks such as finance and book keeping, and new product development for some time. SSRC is responsible for managing the funds from UNDP. This is another reason for their continued involvement in this venture. In addition, SSRC agreed to designate appropriate staff to help the villagers in terms of production, maintenance and sales. After several years, the villagers will be capable to manage the broad aspect of business. In particular, they need to learn financial management. In that regard, SSRC will provide long-term commitment to this venture to develop the capacity of local villagers. At that time, the full hand-over of this venture will be carried out.

In addition, the Ministry of Social and Work Affairs and the Aleppo Authority, as observer, continue to monitor this project and give suggestions as needed. These administrative organizations will, of course, deal with other cottage industry development projects, if any, with their own initiative.

7.1.7 Evaluation of cottage industry and remaining issues

Zarzita which cottage industry was executed in this project can take advantage of its proximity to St. Simeon Castle where many tourists visit. Therefore, sales of handicrafts for these tourists are considered. Key holder and stone powder product, which are popular in Japan as handicraft is proposed. Trial production and technology transfer of these arts to our counterpart was executed in cooperation with UNDP. Sales of products, which produced by SSRC/HIAST and villagers, got good result. However, after the project is finished, there will be some major tasks such as sales channel expansion, new product development. In particular, the production of cloisonn , mold for base metal should be done in Syria for establishing sustainability.

(1) Domestic mold production

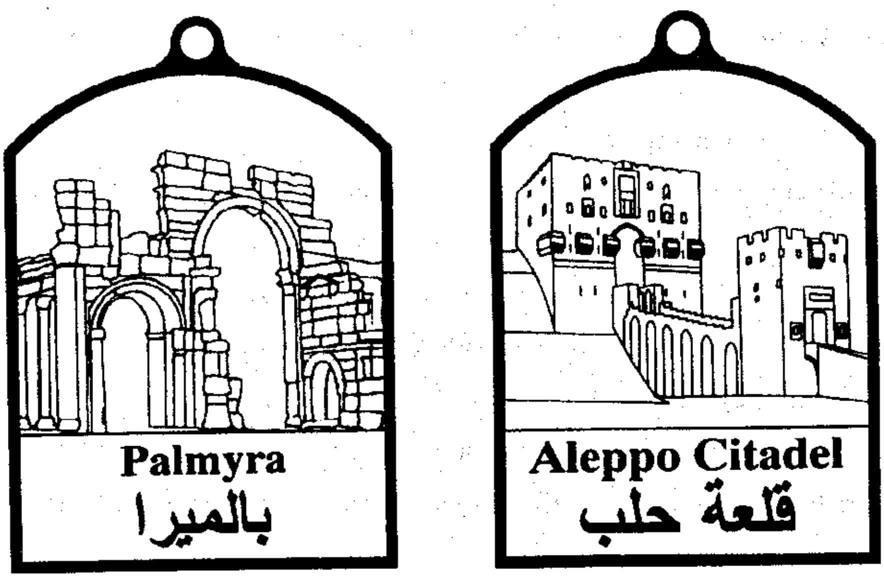
The molds of key holders were all manufactured in Japan. Base metals were processed by using the molds. There are still a large number of base metals as inventory, but the next lot has not been committed. The Syrian side, therefore, should decide whether they import the base metals or make them in Syria before they run out of inventory. If they are going to import, they must pay from their revenue. We studied the manufacturing process of the mold in detail and concluded that the same technology will be available in Syria. An old hand-driven machine, not hi-tech, is used.

(2) Technical improvement and management capacity building

The project team members have mastered the basic technique of production. The next phase would be to train on quality improvement and defect prevention. In this regard, SSRC is expected to visit Zarzita regularly, and to provide coaching for production. More important issue is to give lessons on business management, so that they can manage the whole business as soon as possible. It is often pointed out that Syrian farmers don't have much entrepreneurship, probably because of their long unchanged way of living. Therefore, it was needed to proceed step by step. The first lesson was how to sell your products. After that we could go on to better quality, or cost reduction. It was desired that within five years the villagers could start the management of whole business. Until that time, the support group should give necessary back up both mentally and financially.

(3) Business expansion

It would be possible to expand the business into other areas if the sales at St. Simeon Castle turn out to be successful. The new key holder designs featuring the Aleppo Citadel and Palmyra have been added. Also, a new model of stone powder ornament, which features the Aleppo Citadel, is completed. The discussions to add new sales outlets have been underway. This business plan can be applied to other famous tourist spots in Syria. If the government of Syria starts to promote these tourism related businesses, this JICA project will be viewed as a pioneer venture.



(Palmyra) (Aleppo Citadel)

Fig.7.1-5 New designs

7.2 Effect of introduction of PV system in villages

7.2.1 Items to be surveyed

(1) Survey of daily activity hours

To survey the difference of daily activities in village before and after system introduction.(Time and hours of daily activity)

(2) Survey of impact for daily livelihood

To evaluate the effect of system introduction for villagers (Satisfaction, expectation, change in daily activity, recommendations etc.)

①Effect of introduction of PV system

- Effect of change from lamp lighting to electric lighting
- Effect of introduction of street light
- Effect of increasing hour of watching TV and listening radio
- Effect of increasing hour of study or learning
- Effect of utilization of electric appliances

②Effect of water supply system

- Effect of supply drinking water
- Effect of installation of water supply system

③Acceptance by the users

- Satisfaction to PV systems
- Willingness to pay of electricity fees and its amount
- Effect on the expenditure

(3) Spread effect

Survey about expected spread effect of PV system introduction such as decrease of visiting clinics, increase of literacy and level of higher education, increase of productivity of homework, increase of village night activity, etc.

7.2.2 Survey method

(1) Survey of daily activity hours

In 1998 March to April by interview in Zarzita, Fedre, Katoura

Respondent: Man 54, Woman 41.

(2) Survey of impact for daily livelihood

In 1998 September (additional for Kalif in December) by visiting sample families in Zarzita, Fedre, Katoura and Kalif

Respondent are a head of house, his wife, his son and daughter, the total number of respondent is 195, Zarzita 75、Fedre 28、Katoura 48、Kalif 40 and Man 97, Woman 98.

(3) Survey of spread effects

Surveyed in September 2000, visiting about 40% of users such as Zarzita 19, Fedre 7, Katoura 9, Kalif 9, total 44 users.

7.2.3 Survey result

(1) Survey of daily activity hours

①Time of daily activity

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.

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**

②Change in hours of daily activity

Average hours of daily activities were surveyed.

Hours of activity did not change before and after system introduction were:

For Man: Prayer, Take care of children, Take care of live stocks, Collection of fuel wood Work of farming and Go to town for shopping etc.

For Woman: Prayer, Preparation and finishing of meals, Cleaning their rooms, Kneading of their bread, Take care of children, Take care of live stocks, Collection of fuel wood and Work of farming

Hours of activity increased after system introduction were:

For Man and Woman: Visiting other family, Chattering with family Watching TV, Listening radio and Reading books had.

Hours of activity decreased after system introduction were:

For Woman: Washing in Zarzita as they can use washing machine

Table 7.2-2 Change in hours of daily activity (Man)

Daily activity	Respondents	Before	After	Notes
Prayer	43	1.3	1.3	Max 3.0hr, Minimum 0.5hr
Take care of children	17	2.8	2.8	
Take care of live stocks	35	3.3	3.3	Max12.0hr, Minimum 0.5hr
Collection of fuel wood	12	0.8	0.8	1～2/week
Farming	28	5.6	5.6	Farm period : 1 to 5month/year
Go to town (shopping,)	32	2.0	2.0	1～3/week
Teaching their children	22	1.4	1.8	Max5.0hr, Minimum 0.5hr
Visit other family	43	1.8	2.1	1～3/week
Chattering with family	44	1.8	2.6	Max7.0hr, Minimum 1.0hr
Watching TV	32	0.2	3.8	
Listening radio	41	1.4	3.2	Max 12.0hr, Minimum 0 hr
Reading book	30	1.0	1.4	Max 4.0hr, Minimum 1.0hr

Table 7.2-3 Change in hours of daily activity (Woman)

Daily activity	Respondents	Before	After	Notes
Prayer	30	1.1	1.1	Max3.0hr Min.0.5hr
Preparation and finishing of meal	38	1.7	1.7	Max 5.0hr Min 1.0hr
Cleaning of rooms	38	1.6	1.6	Max 3.0hr Min 0.5hr
Washing	37	3.1	2.8	1～7/week
Kneading of bread	19	2.2	2.2	1～3/week
Take care of children	30			Most of them said all day
Take care of live stocks	25	3.0	3.0	Max 8.0hr Min 0.5hr
Collection of fuel wood	22	< 1	< 1	1 /1～2wek
Farming	14	3.8	3.8	Farm period : 1 to 6 month/year
Visit other family	22	1.6	1.8	1～3/week
Chattering with family	30	1.5	2.3	Max 7.0hr Min 1.0hr
Watching TV	16	0.1	3.4	
Listening radio	20	0.7	2.8	Max 12.0hr Min 0 hr
Reading book	4	0.8	1.1	

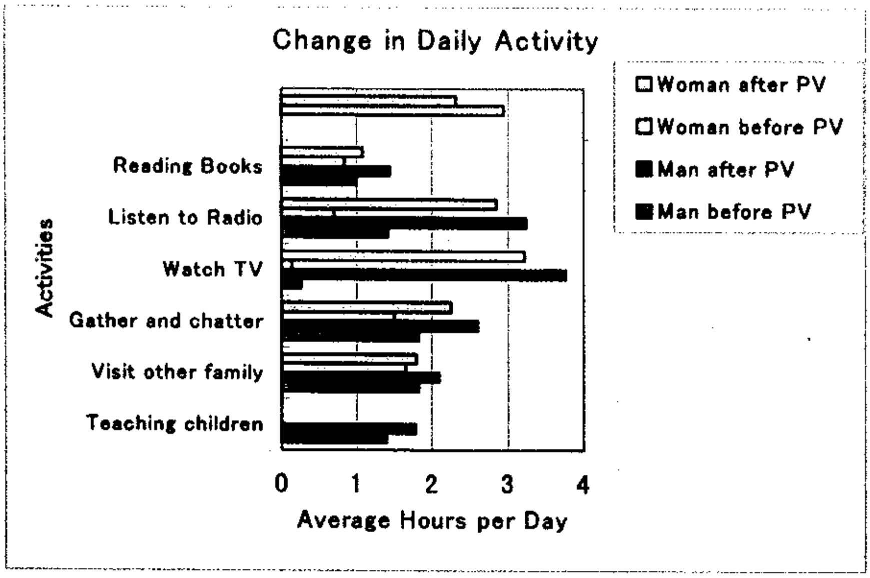


Fig.7.2-1 Change in hours of daily activity

(2) Concrete result in improvement of daily livelihood

The effect and evaluation will be different by the systems to be introduced in villages. Table 7.2-4 is a collective table of what kind of services is supplied to villages.

Table 7.2-4 Introduced system and services for villages

Village	Zarzita	Fedre	Katoura	Kalif
PV system	35kW Centralized	200W Individual	300W Individual	500W Mini grid
Electricity	220V AC	12V DC	12V DC	220V AC
Water supply	PV Pump up	No	No	PV Desalination
Quantity of water (L/day/person)	10～20	–	–	10

L : litter

①Effect of introduction of PV village electrification (Zarzita, Fedre, Katoura, Kalif)

a. Effect of change from lamp lighting to electric lighting

1) Improvement of life environment

The common change in four villages by introduction of PV system is change from kerosene lamp or gas lamp to electric lighting such as fluorescent lamp or incandescent lamp. It improves the cleanliness of air in rooms and health condition of people to reduce stimulation for eyes and respiratory organs. It also reduces the work of cleaning of lamps.

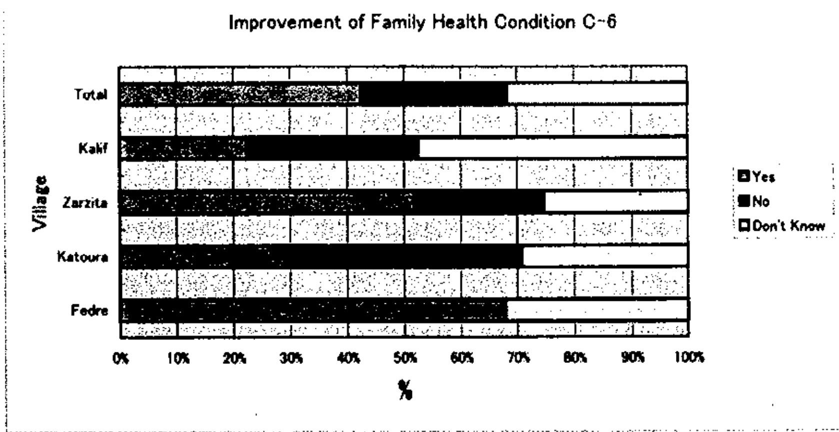


Fig.7.2-2 Effect of improvement for health condition

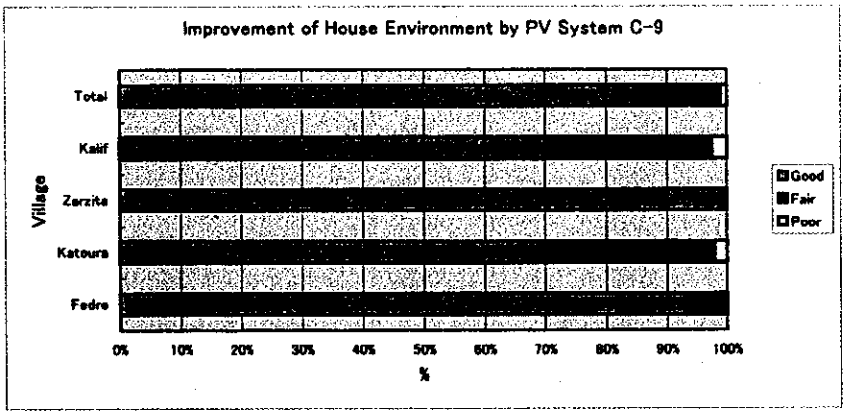


Fig.7.2-3 Effect of improvement for environment in household

2) Improvement of indoor safety and convenience

Before the installation of PV system, families conventionally placed one or two gas or kerosene lamps in the rooms they were using. With the installation, fluorescent lights or small incandescent lamps replaced such lamps, eliminating the danger of breaking such lamps or causing them to leak knocking them over in the dark. Most families now keep small incandescent lamps of 5W to 10W lit all through the night to help family members take care of babies. They are satisfied with these new incandescent lamps because of their safety and convenience.

Table 7.2-5 Number of installed small incandescent lamps (May, 1999)

	Zarzita	Fedre	Katoura	Kalif
Lamps (5W, 10W)	51	13	21	7

b. Effect of installation outdoor lighting

The installation of street lamps and outdoor lights contributed to an improvement in safety during the night. Especially, in Zarzita, all people interviewed recognized a substantial effect on safety.

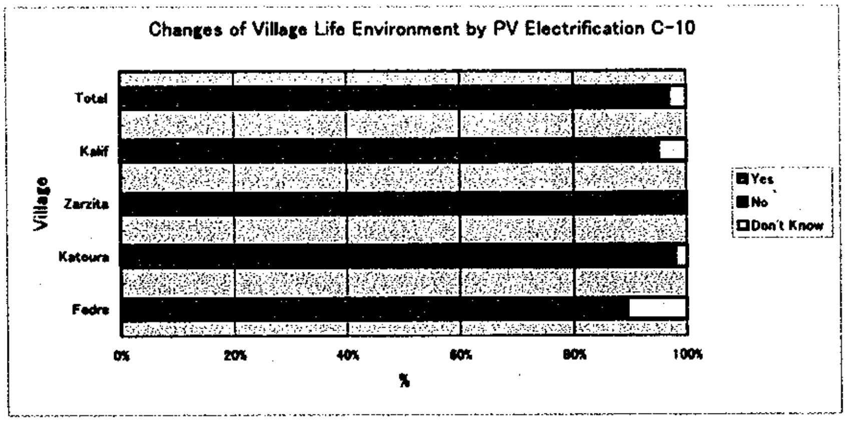


Fig.7.2-4 Improvement of environment of villages

c. Increase in the amount of external information

The installation of the PV system enabled to spend more time for watching TV and listening radio. As larger amount of information were available externally, it became easier for the villagers to obtain advice on farming and to know the current market conditions. Also it makes enrich the kind of hobby or entertainment such as movies, drama and music.

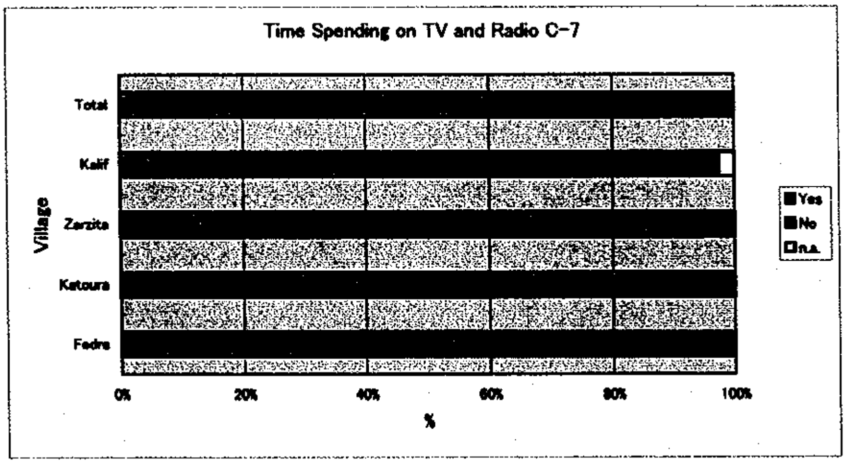


Fig.7.2-5 Effects on television and radio

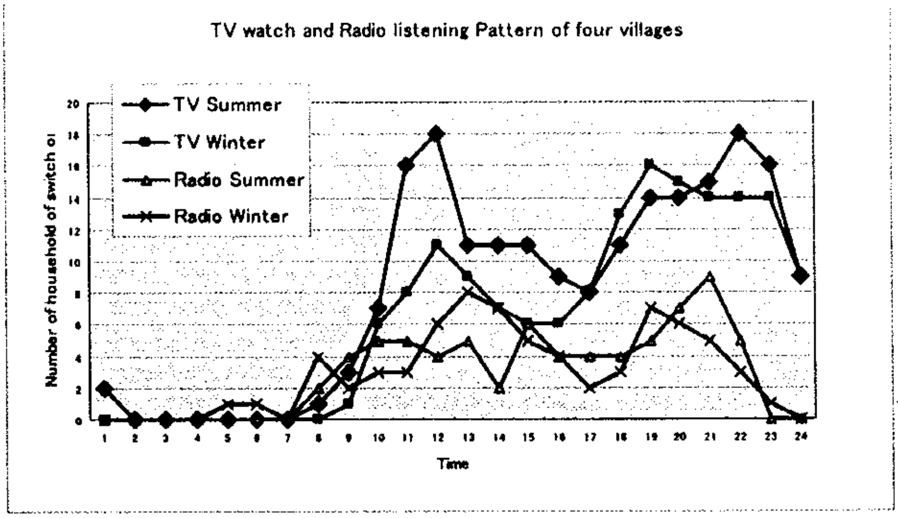


Fig.7.2-6 Distribution of hours for watching TV and listening radio

d. Effects on hours for education

The survey results suggested that longer evening hours became available for education, permitting adults to spend more time on teaching children Koran and characters. The survey results also showed that each household used fluorescent light in more than one room, creating an improved environment for children to study in the evening. This improvement is expected to contribute in the long run to a better literacy rate and encourage more children into receiving advanced education.

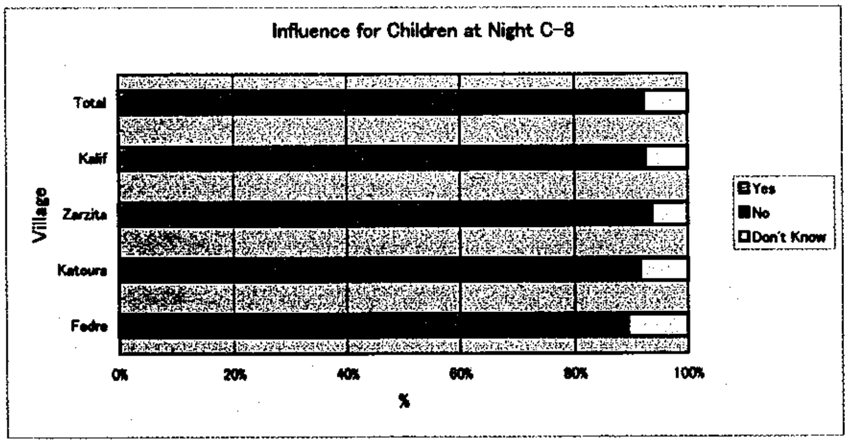


Fig.7.2-7 Effect on evening activities of children

e. Use of electric appliances and saving working hours of women

The appliance that can reduce working hour of women is electric washing machine. The use of washing machine not only cuts washing time and frequency but also saves labor required in the past in hand washing. At the same time, it permits women to engage in other jobs and take better care of their children and families.

Electric washing machines were compatible with the system only in Zarzita and Kalif. In Fedre and Katoura, their systems are incompatible with washing machines but their working efficiency improved in the evening because of the new lighting system.

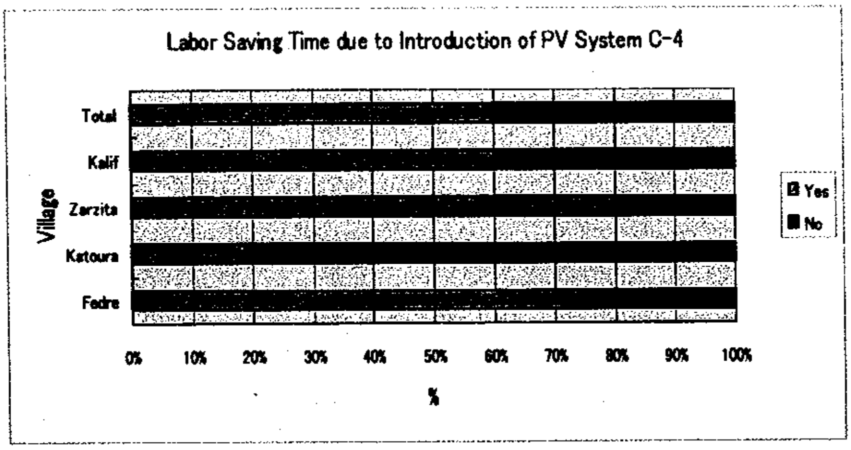


Fig.7.2-8 Effect for reduction of working hours

It is expected by using refrigerator to reserve food in summer season and reduce hours to prepare foods.

But the utilization of appliances such as washing machine and refrigerator is limited only in Zarzita and Kalif, the request of using them in Katoura and Fedre is very strong.

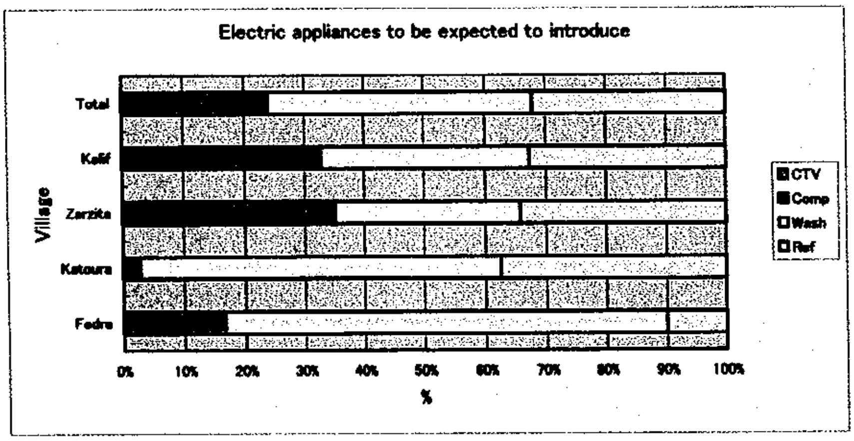


Fig.7.2-9 Appliances wanted to use in household

② Effect of the water supply system (pumping system in Zarzita and pumping/desalination system in Kalif)

a. Improvement in the village environment

Before the introduction of the water system, the villager relied on rainwater and commercial water. After the introduction they benefited a great deal from the acquisition of a water source, although it still did not supply a sufficient quantity of water to meet their needs.

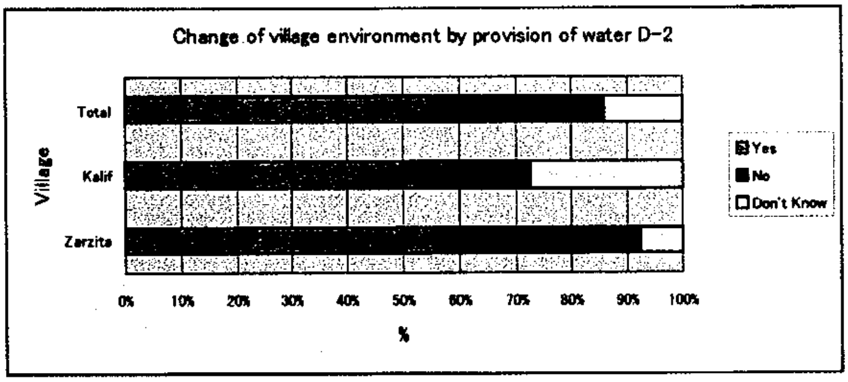


Fig.7.2-10 Effect on village environment

b. Productivity improvement in farming and stock rising

This water supply system secured a quantity of fresh water barely enough to support human life, not covering the increasing number of farm animals. In Kalif, they pumped underground water in quantity several times those of desalinated water. The excess water, which is a difference between water pumped and water desalinated was used for growing salt resistant crops such as olive, cotton and wheat.

c. Reduction in water transportation labor

The water supply system in Zarzita was so constructed that aqueducts were laid from the supply system to a number of supply points within the village. This resulted in less labor than was previously required to distribute water. By contrast, in Kalif the water supply points were located some distance away from the residential area.

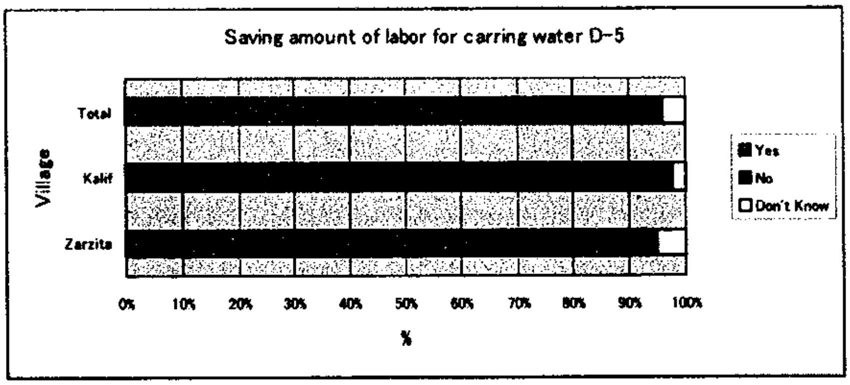


Fig.7.2-11 Effects on labor reduction for water transportation

③Acceptance by the users

a. Satisfaction of the users for systems introduced

The acceptance level (satisfaction) varied according to the system to be installed and service to be provided in each village. Zarzita and Kalif show high level of satisfaction as they were provided AC power and water, on the other hand, Fedre and Katoura are only provided DC power then their level of satisfaction is not so high.

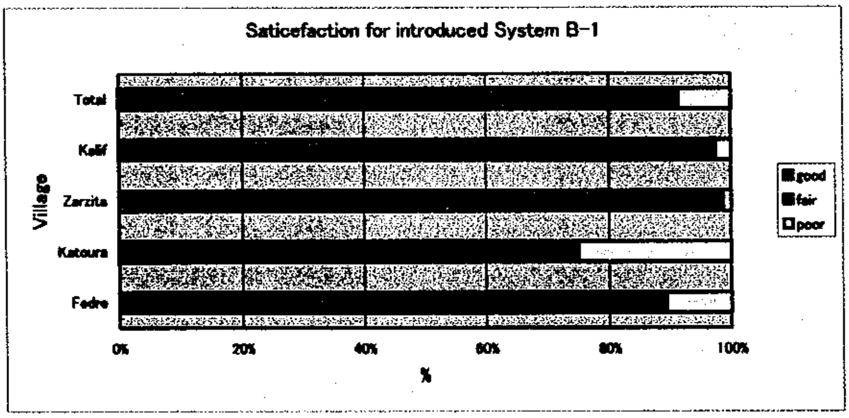


Fig.7.2-12 Satisfaction level for introduced system

b. Willingness to pay for electricity fees

Willingness to pay for electricity fee and expecting amount for electricity fees were surveyed. The willingness to pay electricity fee is high except in Katoura.

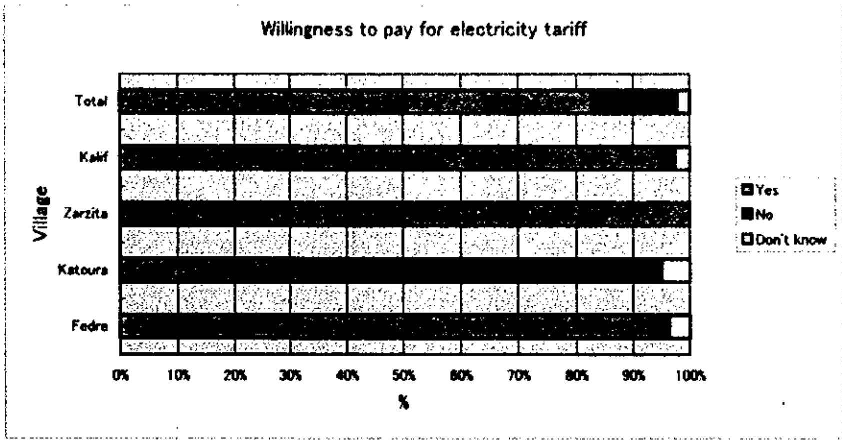


Fig.7.2-13 Willingness to pay for electricity fees

Table 7.2-6 Willingness to pay per month (SP/month)

	Zarzita	Fedre	Katoura	Kalif	Average
Electricity fees	76	97	40	37	64

c. Effect in expense for lighting and water

The amount of expenses for lighting and water purchasing of before system introduction were shown in Table 7.2-7. Electricity fee for respective four villagers are also shown in Table 7.2-7. On the other hand, water fee for Zarzita is 42SP/month/house and that of Kalif is 21SP/month/house. However, Fedre and Katoura are not changed their water situation because water system was not introduce.

Table 7.2-7 Expense for lighting and water

	For lighting (SP/month)	For water (SP/month)	For electricity fee (SP/month/house)
Zarzita	192	398	62
Fedre	140	465	45
Katoura	121	315	67.5
Kalif	101	154	112.5(per system)

Survey in September 1998
Price of purchased water was around 250 SP/4m^3

④Summarization of PV system introduction effect

Table 7.2-8 is a summary of effects in improvement of village life that is expected by introduction of PV system and the level of realization of them.

Table 7.2-8 Summary of expected effects and level of realization

System	Change of situation	Expected effects	Level of realization
PV electrification (Zarzita, Fedre, Katoura, Kalif)	Kerosene lamp to fluorescent lamp or incandescent lamp	Improvement of environment in household. Improvement of safety and convenience in household	Middle*1 Large
	Installation of outdoor lighting	Improvement of safety at night in the village	Large
	Increase of hours for watching TV and listening radio	Increase of external information. Enrichment of hobby and entertainment	Large Middle
	Increase of hours for study and education	Improvement of scholarship	Middle
	Utilization of electric appliances	Reduction of labor of women	Small～Middle*2
	Utilization of electric tool or machine	Enhancement of income resources	None*2
	Saving of expense for lighting	Saving of expense	Middle
Water supply system (pumping and desalination) (Zarzita, Kalif)	Securing of water for drinking	Improvement of living environment	Middle
	Utilize of excess water	Increase of productivity in agriculture and live stock	Small*3
	Installation of aqueduct	Reduction of labor of water transportation	Middle*4
	Reduction of purchasing water	Saving of expense	Middle

Level of realization (basically)

Large: More than 80% of users are satisfied

Middle:50 to 80% of users are satisfied

Small: Less than 50% of users are satisfied

*1: The lighting was changed but fuel for heating and cooking is still kerosene, woods and dried dung.

*2: Utilization of electric appliances, tools and machine is possible only in villages of Zarzita and Kalif.

*3:Excess water is available only in Kalif

*4:Aqueduct is installed only in Zarzita

(4) Spread effects of introduction of PV systems

A plain result of spread effect of the introduction of PV systems is an increase of household in Zarzita. Before introduction of PV system, there were 40 households and after introduction of PV systems there are 53 households. 13 households are increased during three years after introduction of PV electricity and PV water supply system. The Table 7.2-9 is expected spread effect by introduction of PV system that users evaluated

Table 7.2-9 Expected spread effects

Direct effect	Expected spread effect	Yes (%)	No (%)	No Idea(%)
Reduction of soot by change of kerosene lamp to electric lighting	Reduction of repainting of the wall and ceiling of room as stains of wall and ceiling will be decreased.	73	27	0
The air in the room turned more clean than before.	Reduction of illness in respiratory organs, visit to clinic will be decreased.	59	23	18
Increase of communication between families and within family	Increase intimacy between families and within family	77	23	0
Increase of hours for study and education	Increase an awareness for education and raise a rate of literacy and rate of advanced education	68	30	2
Possible to use electric appliances	Improve productivity of home works and increase the production of home works	48	48	4
Improve safety by installation of outdoor lighting	Improve activities at night in the village	80	20	0
Increase hours for watching TV and listening radio/cassette	The life of village becomes more comfortable	86	14	0
Reduce working hours of women by using electric appliances	Increase free hours of women and increase women to join cooperative activities of village	45	55	0
Possible to use speaker system of Mosque	Improve communication of information in village and cooperation of village become intensified	61	23	16
Cultivate agriculture plant using excess water	Increase production and sales of agricultural products	0	100	0

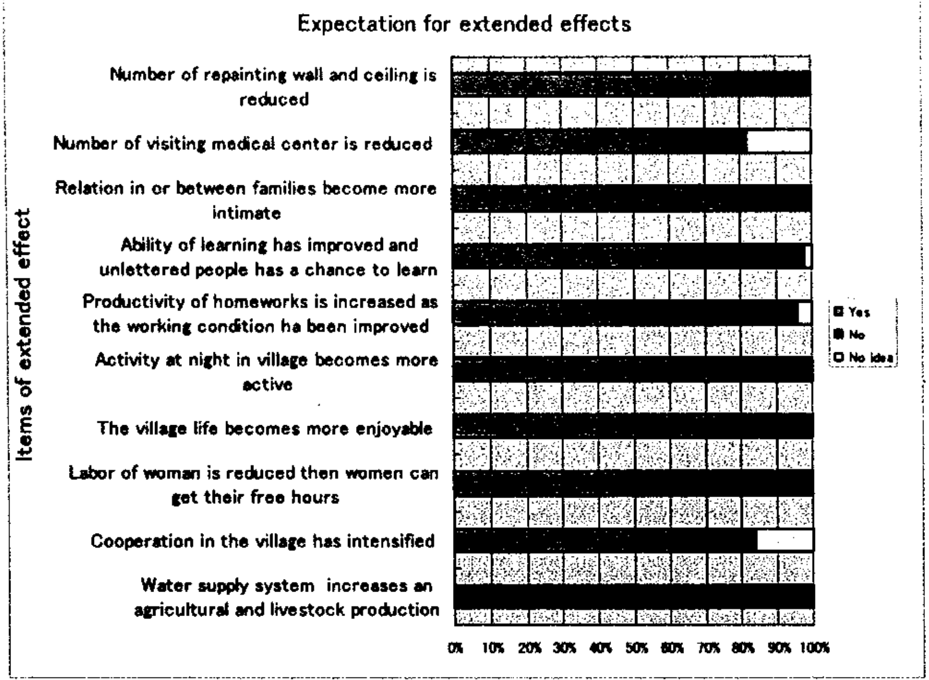


Fig.7.2-14 Expectation of spread effects

7.2.4 Overall effects for improvement of livelihood

(1) Overall effects

①Effects of project

Table 7.2-10 is shown the conditions of improvement for village livelihood and expected effects by the introduction of PV systems. In many cases, the introduction of PV system contributes to improve village livelihood, but except the introduction of cottage industry in Zarzita, there is no significant effect to improve income generation of village by the introduction of PV system.

②Acceptance by the users

The acceptance level (satisfaction) varied according to the socioeconomic conditions of the village and the specifications of the system introduced. The acceptance level may have varied due to a gap between expectations and services actually offered by PV systems.

Table 7.2-10 Conditions of improvement for village livelihood and expected effects by introduction of PV systems

Conditions of improvement	Expected effects by PV system	Realization
Conditions in household		
Improve safety and convenience of daily life	Change from kerosene lamp to electric lighting reduces oil spillage, damage of lamp, and fire	Yes
	Installation of outdoor lighting	Yes
	Utilization of small incandescent lamp for lighting through all the night	Yes
Improve sanitary condition and spend comfortable life	Change from kerosene lamp to electric lighting reduces soot, smell and noise in the room	Yes
Easy to get water, food and energy	Supply electricity at least for lighting and TV/radio	Yes
	Supply drinking water in Zarzita and Kalif	Yes
Increase income or increase means of income generation	Improve productivity of home works by utilizing electric appliances	Not yet
	Utilization of electric tools and machines for manufacturing	Yes
	Increase of agricultural production by supply of water	No
Decrease of expense	Decrease of purchasing water (Zarzita, Kalif)、	Yes
	Decrease of purchase for lighting and dry cell for radio	Yes
Easy to get external information	Increase hours for watching TV and listening radio	Yes
Increase the chance of education and secure the hour to study	Increase hours for study and education in household	Yes
	Install the lighting in schools	Yes
	Increase free hours by improving efficiency of home works	Yes
	Reduction of works water carrying	Yes
Improvement of intimacy between families and within family	Increase hours for chattering under electric lighting between families and within family	Yes
Enrich kind of hobby and entertainment	Increase hours for watching TV and listening radio/cassette and enjoy for cinema, drama and music	Yes
Conditions in village life		
Improvement in safety, environment, and sanitary in the village	Installation of streetlight in Zarzita	Yes
Activation of village economy by increase of job and commercial activity	Introduction of cottage industry in Zarzita	Yes
Improvement of educational facility	Installation of lighting at school	Yes
Improvement of co-operational facilities	Supply electricity for speaker of Mosque	Yes
	Installation of streetlight	Yes

Table 7.2-11 Expectations and services provided by PV system

Village	Expectation	Services provided	Acceptance
Zarzita	High	AC 220V 35kW/40 households, Water supply system, cottage industry	High
Fedre	Middle	DC 12V 200W/household	Middle
Katoura	High	DC 12V 300W/household	Low
Kalif	Middle	AC 220V 500W/2~3household Water supply system	High

Expectation High: Expect electricity for washing machine and refrigerator

Middle: Expect electricity for lighting and TV/radio

Acceptance High: Satisfaction is high and willingness to pay is high

Middle: Satisfaction is fairly high and willingness to pay is high

Low: Satisfaction is low and willingness to pay is low

- In Zarzita, expectations were high. Except for quantity, services allowed the use of PV system electricity in the same manner as with conventional electric power. Further, a water supply system and a cottage industry was introduced then the satisfaction is high and willingness to pay electricity fee is also high.
- In Fedre, people accepted the system after it was explained to them that PV system would only apply to lighting, TV and radio. They welcomed PV electricity and agree to pay electricity fees.
- In Katoura, PV system could not operate washing machines they were already having. They are strongly expecting to get conventional electricity. This made the resident less satisfied and willingness to pay electricity fee is low.
- In our initial plan, Kalif was not included as a subject of the study. The villagers accepted PV system with satisfaction due to the unexpected introduction of electricity and water service by PV system.

(2) Spread effects

As described before, the direct effects of the introduction of PV system in un-electrified village had been realized already. The spread effects caused by direct effects are surveyed.

A plain effect of introduction of PV system appeared in the village is an increase of a number of household in Zarzita. Before introduction of PV system, there were 40 households but after three years there are 53 households in the village.

In other three villages, there is no change in the number of households, only in Zarzita significant increase in number of households and it bring a problem how to provide enough supply of electricity and water from limited supply sources.

For other expected spread effects, as positive expectation:

Decrease number of repainting of wall and ceiling, decrease number of visiting clinics, improvement of literacy rate and rate of advanced education, improvement of a comfort of village-life, activation of village activity at night and improve intimacy by increase of communication.

As negative expectation:

Improve productivity by utilization of electric appliance increase free hours of women from saving of working hours by utilizing electric appliances and increase of sales of agricultural product by using excess water pumped.

Chapter 8

Economic Analysis of PV Systems

Chapter 8 Economic Analysis of PV Systems

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

(1) Economic analysis of PV systems

①Review of the unit prices of PV system components

In recent years efforts of developing PV system have been activated in advanced industrial countries and prices of PV system components have been showing a strong trend of decrease. To be more specific, in the Draft Final Report No.1 the unit prices of various PV system components were estimated for 2000, and comparison of these estimates and the actual unit prices at the beginning of 2000 showed a decrease of 20% in the price of the module and also large decreases in prices of various components (this point was made by SSRC/HIAST). Accordingly, relevant information was analyzed and unit prices of relevant components for 2000 and 2005 were reviewed.

②Economic comparison between kerosene lamp/battery-powered TV and PV system

In un-electrified villages, younger households use kerosene lamps for lighting and purchase car batteries to power a TV. This can be practiced widely in un-electrified villages. We assume that the costs of this practice equal the benefits. The costs of a 60W individual PV system (which has more functions than kerosene lamp and battery-powered TV) are calculated. Then some economic indicators such as (benefit - cost) and (benefit/cost) are examined. The economic internal rates of return (hereinafter called EIRR) of PV systems are examined using its economic prices as well.

(2) Planning materials of use of various PV systems

Generating costs and water costs are examined for electrification, water pumping and desalination with PV systems.

①Electrification with PV system

Mainly the generating costs of individual PV systems and the mini-centralized PV systems are compared with the costs of grid extension and diesel power generation. As for the individual PV systems, five different system scales are examined, and as for the mini-centralized PV systems, three different system scales are examined. Water pumping costs using surplus electricity are examined for the respective scale of mini-centralized PV system as well.

②Water pumping with PV system

Various head and capacity are used as parameter and PV water pumping cost and water cost with diesel engines are examined.

③Desalination with PV system

As for desalination, some specific sites such as Badia area in the southeast of Hama where Bedouins live are selected and production costs of fresh water are examined for RO membrane method and ED method. The qualities of brackish water are taken into consideration.

8.1 Cost assumption of PV system components

As mentioned above, prices of PV cells have been showing a significant tendency to decrease in recent years. This trend is considered to be the results of the efforts of advanced industrial countries in reducing emission of gases including CO_2, which are related to the global environmental problems, and increased people's interests in such problems.

Here we will overview the efforts in promoting PV system in some major advanced industrial countries, and examine the actual prices of PV cells and balance of systems in 2000 and estimated prices of such components in 2005 when Syrian side can fully engage in PV system.

8.1.1 State of promotion of PV system in some major advanced industrial countries

The state of promotion in some major industrial countries including the U.S.A, Japan and Germany will be outlined below.

(1) U.S.A

In the U.S.A, in particular in the State of California, new facilities of 20MW were installed in 1999 because of the Y2K problem of computers (in relation with possible interruption of power supply) and thanks to the subsidy of US$3/W by the State. It was the largest annual increase ever. However, it has been pointed out that the generating cost of PV system in the U.S.A cannot be economical without subsidies until 2010. The State of California is suited for PV system, where the sunshine is abundant and the electricity fees are two times as high as the average of fees in the USA. Moreover, the State of California has been positive in coping with the environmental problems and institutional frameworks have been established there. It is said that in the State of California the conditions for the generating cost of PV system to be competitive with the electricity fee of the grid are, when the PV system facility cost is US$7/W in 1999, the subsidy is US$3/W, the interest rate on loan is 8%, the term of redemption is 20 years and the refund of tax is 15%.

On the other hand, the production of PV cells in the USA in 1999 was 60MW. 20 MW out of 60MW was used domestically and the remaining 40MW was exported. The breakdown of 20MW that was used domestically is 4MW for grid connection, 6MW for off-grid consumer, 2MW for governmental project, 6MW for off-grid industrial uses, and 2MW for commercial uses. As for the future prospect, it has been pointed out that if the growth rate of PV system is 15% or over, cost reduction can be expected and expansion will be accelerated.

(2) Japan

As PV system generates power using clean energy, it is a very effective power generation technology for environmental conservation. Hence the government of Japan has been considering PV system as one of promising technologies and promoting its technology development and introduction through the Sunshine Project. Here we will focus on the latter promotion and the power generated cost of PV system.

As for promotion of introduction of PV system, demonstrative studies were made as "Projects for Monitoring PV Systems for Residential Use" in the past. Since 1997, under a new subsidy system, expansion of PV system has been promoted through "Projects for Developing the Basis for Introducing PV system for Residential Use." As a result, as of the end of 1999, PV systems were installed on about 35,000 houses. The subsidy was 50% of the installation cost at the initial stage, but at present it has been reduced to about 30%. Japanese people's interest in PV system is such high that the number of subscription for the subsidy exceeds the target in several days. When the PV system cost is US$8/W, the generation cost of PV system is US$0.52/kWh without subsidy. When the subsidy is 35%, the generating cost is US$0.27/kWh, which is close to the electricity fee of US$0.217/kWh. The present subsidy system will be terminated in 2002, but before that at most efforts will be exerted to promote technological development to improve economic situation of PV system. The target of production capacity of PV system by 2010 is 5 million kW. The installed capacity of PV systems in Japan as of the end of 1998 was 133,000kW and it was the largest in the world. It was followed by the USA with 100,000kW and Germany with 50,000kW.

(3) Germany

Peoples of German has been showing high interest in environmental problems, and the government of German, striving to promote the use of clean energy power generation, has been planning and implementing PV system introduction projects including various subsidies to give greater incentives to the people as well as the PV system market.

A recent established program is that 100,000 of grid connected PV systems will be installed on roofs of residential houses and commercial houses. The plan is based on the new renewable energy act, which was passed in the Parliament in early 2000. The plan is actually a subsidy system wherein no payment is required in the first year and after that, 99 pfennigs/kWh are to be paid for fee of PV system power generation. As this rate was 65 % of the electricity fee, in the first four months of 2000, 2,000 of subscription, which were equivalent to 70MW were made, whereas the installation in 1999 was 11MW. Based on such dramatic increase, the government reviewed the amount of the subsidy and lowered.

In the past, the government of German planned and implemented various programs including subsidies such as the plan of 1000 roofs top PV systems and 2000 roofs top PV system. However, in spite of the positive measures by the government of German, at present there are no manufacturers of PV cell in Germany, and Germany is dependent on imports from the U.S.A, etc. Hence a new production plant for 50MW per year is under construction, and production procedure using new technology are under consideration.

(4) Other countries

Efforts are also made in Switzerland, Italy, Holland, Spain, Australia, etc., and greater developments are expected around 2005.

8.1.2 Price trends of PV cells

At present, the generating cost of PV system is not competitive with the electricity fee of the conventional grid. Hence, as mentioned above, in some major advanced industrial countries, based on the governmental assistance, enlightenment and measures to activate industries related to PV system are considered. In recent years, the generating costs of PV system have been closing to about twice as a conventional electricity fee although depending on the electricity fees of the respective countries. It is expected that the cost of PV system will become competitive with the electricity fees by 2010, although again depending on the measures of the respective governments and technical development of PV systems. Once such a state is reached, PV system will make a rapid growth.

In the markets of PV systems in Europe and USA, the U.S.A being the largest production center presently has the casting vote in price determination. As the U.S.A. is exporting 60% of its production of PV cells to Europe, etc., the prices of PV cells in the U.S.A. market will be reflected in the prices in Europe for the time being. The present prices and estimated future prices in the PV cell market in the U.S.A are as shown below.

Table 8.1-1 Prices of PV system for grid connection in U.S.A. by 2010

Year	1999	2000	2005	2010
Module unit price (US$/W)	3.50 – 5.00	3.00 – 5.00	1.75 – 2.50	1.00 – 1.5
Unit price of facility (US$/W AC)	7.00 – 9.00	6.50 – 8.00	5.00 – 6.00	2.00 – 3.00
Installed capacity (MW/year)	55	70	120	240

Note)1. Source: Renewable Energy Review Issue 2000-2001 Vol 3 No 4.

This assumption is based on that the financial assistance by state governments will continue till 2003 like that of the State of California. According to this assumption, cost reduction will be the largest between 2002 and 2004, and governmental assistance will be stopped gradually.

8.1.3 Cost assumption of PV system components

In the previous subsection, unit prices of PV cells and unit prices of facility of grid connected PV systems in the U.S.A and Europe were examined. It, however, is not enough to assume costs of stand-alone PV systems in rural areas on the basis of the above-mentioned information. Fortunately, SSRC/HIAST have been collecting information on various PV systems, and among such information is included "Kyocera Solar International Dealer Price List" of Kyocera USA. The list covers unit prices of components of various manufacturers in the U.S.A and Japan. The information of this document and the above-mentioned unit prices of future PV system in the U.S.A were used in combination to estimate the unit prices of the respective components in 2005. The results were as follows. It should be noted that Kyocera U.S.A was established in November 1999 and the company issued its dealer catalogue immediately and the company revised the catalogue in April 2000. The catalogue that was published immediately after the establishment is considered to show prices of components around 1998. Hence prices indicated in the first catalogue and those indicated in its revision were compared with each other to calculate the rates of price down in about two years.

(1) Unit prices of modules

The prices of a various types of modules as of January 2000 were estimated by multiplying the prices indicated on Kyocera catalogue with the ratio of module price down from 2000 to 2005 in the U.S.A.

Table 8.1-2 Assumed unit prices of modules in 2005

Part number	Output (W)	Unit price in April 2000 (US$)	Unit price in 2005 (US$)	Remarks
15484	120	492.3	262.2	
15483	80	329.5	175.5	
15482	60	255.1	135.9	
15481	40	185.9	99.0	

Notes) 1. Ratio of price drop of module in the U.S.A. 0.533/5 years (2.13/4)

(2) Unit prices of charge controllers

As charge controllers use power electronics, their unit prices are functionally related with the unit prices of modules, but to be on the safe side, a drop of 30% is assumed.

Table 8.1-3 Assumed unit prices of charge controllers (for 12V)

Part number	Current (A)	Unit price in April 2000 (US$/A)	Unit price in 2005 (US$/A)	Remarks
32380	8	6.09	4.26	0.70
32367	12	4.74	3.32	0.70
34966	10	5.02	3.51	0.70
34935	20	3.39	2.38	0.70

Note) Remarks indicate the ratios of price drop of the catalogues (in about 2 years)

Table 8.1-4 Assumed unit prices of charge controllers (for 24V)

Model number	Current (A)	Unit price in April 2000 (US$/A)	Unit price in 2005 (US$/A)	Remarks
34942	10	5.43	3.80	0.70
34936	20	3.94	2.52	0.70
37002	60	2.99	1.39	0.67
33686	25	4.46	3.12	0.65
33685	35	2.80	1.96	0.65

Note) Remarks indicate the ratios of price drop of the catalogues (in about 2 years.)

As the ratio of price down in about two years indicated in the remarks is 35%, 30% of cost reduction can be safely expected by 2005. When unit prices of charge controllers for 12V and those for 24V are compared with each other, generally the prices of the controllers for 24V is cheaper than that of 12V. In applying a specific unit price, an average of unit prices of charge controllers for each voltage was calculated; US$3.37/A was used for 12V and US$2.56/A for 24V, respectively.

(3) Inverters

In the last two years approx., 25 to 35% of cost reduction was marked. This tendency is considered to continue in future, and 30% of cost down like that of the controllers is expected by 2005. The results of calculation were as follows:

Table 8.1-5 Assumed unit prices of inverters (24V DC /230V AC)

Part number	Capacity (VA)	Unit price in April 2000 (US$/VA)	Unit price in 2005 (US$/VA)	Remarks
49910	200	0.19	0.14	0.75
49912	500	0.11	0.08	0.75
49914	2000	0.14	0.10	0.75
49916	3000	0.14	0.10	0.75
50901	3300	0.67	0.47	0.63
51016	1500	0.45	0.31	0.66
51008	2400	0.38	0.27	0.65

As prices difference is significant among manufacturers, it was decided to use the average of the unit prices, US$0.24/VA. According to the catalogue, products wherein an inverter and a controller are integrated with each other are available now. However, as the specifications of such products are not certain, they are omitted from the consideration. Such components will be used in future to improve the economies of PV systems.

(4) Batteries

Batteries that are considered to be promising for PV system were selected from a large number of battery products, and their unit price trends were examined. The results are as follows:

Table 8.1-6 Assumed unit prices of batteries

Type	Part no.	Voltage (V)	Capacity (Ah)	Unit price in April (US$/Ah)	Unit price in 2005 (US$/AH)	Remarks
Seal	42192	12	48	1.45	1.05	0.67
	42191	12	72	1.55	1.09	0.72
	42193	12	85	1.37	0.96	0.64
	42189	12	105	1.24	0.86	0.63
	42198	12	255	1.18	0.82	0.67
	42202	6	220	1.26	0.88	0.72
Wet	[redacted]					
	40427	12	130	0.54	0.38	0.72
	40428	6	400	0.77	0.54	0.72
	40446	6	682	1.11	0.78	0.69
	40446	6	854	1.11	0.78	0.69
	40465	6	1025	1.12	0.78	0.69

Notes) 1. Ah is V-based, 2. Part no. 40426 is for stand-alone use.,
3. Part no. 40446 guarantees 10 years of useful life.

Recently, there is a tendency to shift from the wet type batteries to the seal type batteries. The reason for adopting the seal type batteries is as follows. The wet type batteries are used mainly as emergency power sources, and if the wet type batteries are not maintained properly, for example, replenishing the liquid, they may fail to work when they are needed.

At present, the unit prices of the seal type batteries are higher than those of the wet type batteries because of their maintenance-free features. As for the figures of the ratio of price down is shown in the remarks, the wet type batteries have a little larger figure. The results obtained by setting the ratio of unit price drop by 2005 at 30% are as shown above. In the present analysis, US$0.34/Ah of the most inexpensive part number 40426 for PV system was used.

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	42189	12	105	1.24	0.86	0.63
	42198	12	255	1.18	0.82	0.67
	42202	6	220	1.26	0.88	0.72
Wet	**40426**	**6**	**250**	**0.48**	**0.34**	**0.72**
	40427	12	130	0.54	0.38	0.72
	40428	6	400	0.77	0.54	0.72
	40446	6	682	1.11	0.78	0.69
	40446	6	854	1.11	0.78	0.69
	40465	6	1025	1.12	0.78	0.69

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8.2 Economic analysis of PV systems

When plant and equipment investment is to be made, its economic analysis is very important. When a decision is made and once a facility is constructed, the facility which funds have been invested cannot be replaced even if an unexpected event should happen. Hence, in developing a facility plan that provides the basis of the investment, various conditions should be identified and considered comprehensively. In such a case, economic analysis is used in fields where some quantifiable aspects of alternative facility plans are examined. One feature of this analysis is that under a given condition all costs, which are needed in planning alternative facilities, are identified to make case studies, and a case wherein the total sum of the present values of these costs is minimal is judged to be optimal. Then aspects that cannot be quantified are taken into consideration to make the final plan.

For example, in case of planning a complicated power source development, demands are assumed, and to keep constant supply reliability, various factors for new power sources such as hydro, thermal and nuclear power plants are provided. Then according to those assumptions, a new power source is set up to satisfy the reliability considering the repair and maintenance plans. The sum of the present values of the fixed cost for the new power source and the fuel expenses of the new and existing facilities is lowest, this case is considered to be the best mix of power source development.

On the other hand, economic analysis of introduction of PV systems in a rural area is simple. However, the approach of analysis is a same procedure. In the following, the basic concept of analysis is described and economical effect of the introduction of PV systems to un-electrified village is studied comparing with use of kerosene lamps and battery-powered TV.

8.2.1 Concept of economic analysis

When an investment in equipment (including purchase of a house, etc.) is to be made by a person or an enterprise, funds are procured from a bank, etc. In case of a person, this investment gives comfortableness as compensation. In case of an enterprise, the investment gives profitability as compensation. The procured funds must be repaid within the predetermined term. There are various repayment methods including fixed installment method, fixed percentage method, and methods with some exceptions. In any case, the total sum of present values of the payments within the term at an interest rate "i" is same. For example, if the procured funds "A" are paid back immediately, the repayment is "A". In an extreme case, if the repayment is to be made at a time after "n" years, the present value of the repayment at the time is A x $(1+i)^n/(1+i)^n = A$, and there is no difference. However, the repayment at the time is necessarily A x $(1+i)^n$ that includes interests. In economic calculation it is convenient to use a method in which the annual repayment plus interest is the same every year throughout the repayment term. In this case, the total sum in present value "A" for the "n" years of repayment period is given by

$$A = \sum_{n=1}^{n} \frac{a}{(1+i)^n} = \frac{(1+i)^n - 1}{(1+i)^n i} a$$

and "a" is given by

$$a = \frac{(1+i)^n i}{(1+i)^n - 1} A$$

The coefficient $(1+i)^n\, i/((1+i)^n - 1)$ is called the Capital Recovery Factor (hereinafter called CRF). A PV system comprises various components having different lives, such as PV module, inverter, controller and battery. Hence the annual costs of each components is calculated by applying different CRF, which reflect different lives of various components, and the facility cost of PV system is determined by summing those annual costs. When the inflation "f" is taken into consideration, $(1+f)^n$ that is considering the inflation for the period of replacement of each component should be reflected on the initial acquisition cost.

In addition to them, personnel expenses and repair and maintenance expenses are needed to operate and manage PV system. Normally, the former facility cost is fixed and called the fixed cost. The latter expenses fluctuates depend on the conditions of respective components and called variable costs. All fixed and variable costs relating to PV system should be identified and calculated for the useful life of the major component, in the present case, 20 years used for the useful life of PV module. The annual expenses comprising the fixed costs and the variable costs are converted to the present value by applying the interest rate "i". Then the total sum of expenses over the useful life is obtained. When this total sum of expenses is multiplied by the CRF, the annual expenses equalized over the useful life is got.

The interest rate "i" usually change depending on business fluctuation. When business activity revives and there is fear of inflation, the interest rate "i" will be raised. When business activity slackens, the interest rate "i" is reduced to encourage investment in equipment. It, therefore, is important to make investment with due attention to the trend of interest rate.

8.2.2 Economic comparison between kerosene lamp/battery-powered TV and PV system

Kerosene lamps are normally used for lighting at night in un-electrified houses. The number of 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. It is a role of housewife to clean the lamp chimneys and refuel the lamps. In households with young men or women, they use radio cassette player powered by dry batteries. In more affluent households of young residents, they watch DC-powered TV using car batteries.

In the following, we consider households, which are relatively advanced in the use of electric appliances in un-electrified houses. We assume the use of kerosene lamp and battery-powered TV and compare their costs with the costs when a PV system is installed to provide power equivalent to the services of the former.

The starting time point of comparison is 2005 when such PV systems can be practically installed. The period of cost comparison is 20 years, which is the useful life of PV system. It should be noted that lighting expenses and car battery expenses, which are spent by the farmers, are assumed to be constant because prediction of their prices are difficult. On the other hand, as the price trend of PV system components over five years are stable, they are reflected in this comparison. It is also assumed that there will be no inflation over 20 years (this is the assumption made by SSRC/HIAST).

The study team made interview surveys about these expenses in rural area. Kerosene consumption for lighting and the number of charging batteries per month showed some dispersion. These expenses are summarized as follows:

(1) Assumption of lighting and batteries

①Kerosene lamps

Price of lamp equipment	**US$ 4**
Useful life of equipment	**5 years**
Kerosene consumption per month	**30 liters**
Kerosene price	**US$ 0.14 /liter**
Estimated equivalent power of lamp 1	**20 W**
Estimated equivalent power of lamp 2	**5 W**

Using hours of lamp 1 (at night) 5 hours/day

Using hours of lamp 2 (bedtime) 8 hours/day

②Battery for DC TV

Price of battery US$ 30

Useful life of battery 1 year

Number of charging per month Twice / month

Cost of charging US$ 1.5 / charge

TV capacity 12 W

Using hours of TV 5 hours/day

(2) Expenses of kerosene lamp and battery-powered TV

On the basis of the above-mentioned assumption, costs related to kerosene lamp /battery-powered TV was calculated at an interest rate of 6.5% as follows.

Table 8.2-1 Annual costs related to kerosene lamp/battery-powered TV (US$)

Year	Fixed cost	Variable cost			Total
	Lighting equipment etc.	Kerosene expenses	Battery charging expenses	Subtotal	
1	32.2	50.5	36	86.5	118.7
2	32.2	50.5	36	86.5	118.7
3	32.2	50.5	36	86.5	118.7
4	32.2	50.5	36	86.5	118.7
5	32.2	50.5	36	86.5	118.7
6	32.2	50.5	36	86.5	118.7
7	32.2	50.5	36	86.5	118.7
8	32.2	50.5	36	86.5	118.7
9	32.2	50.5	36	86.5	118.7
10	32.2	50.5	36	86.5	118.7
11	32.2	50.5	36	86.5	118.7
12	32.2	50.5	36	86.5	118.7
13	32.2	50.5	36	86.5	118.7
14	32.2	50.5	36	86.5	118.7
15	32.2	50.5	36	86.5	118.7
16	32.2	50.5	36	86.5	118.7
17	32.2	50.5	36	86.5	118.7
18	32.2	50.5	36	86.5	118.7
19	32.2	50.5	36	86.5	118.7
20	32.2	50.5	36	86.5	118.7

Fixed cost includes those of kerosene lamps and batteries. Useful life of the former is five years, and that of the latter is one year. Fixed cost of each is the acquisition price of equipment multiplies the CRF under the interest rate of 6.5 %. Kerosene price of equipment multiplies the CRF under the interest rate of 6.5%. Kerosene expenses and battery charging expenses, which constitute the variable cost, are based on the annual consumption and the annual number of charging. Consumption of power that is equivalent to the lighting and battery TV under the conditions of the above-mentioned assumption is 73kWh per year. The annual cost for related to the kerosene lamp and TV is US$118.7 of Table 8.2-1, and unit price is US$1.6/kWh.

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/CRF) at the interest rate of 6.5%; US$118.7/0.090756 =US$1,307. 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 lamp and TV watching with car batteries.

<Remarks>

Life of car battery is short about one year. This is caused by use of battery that is almost same as dry battery. Once a battery is over-discharged, performance of battery is extremely degraded.

8.2.3 Case of introduction of PV system

An alternative to kerosene lamp and battery-powered TV in un-electrified villages is grid extension and PV system. Grid extension is executed according to the plan of the Electric Authority; it is planned to electrify about 100 villages a year. However, it is hard to say that every village is within the scope of electrification. On the other hand, PV systems are stand-alone and can be installed anywhere they are needed. When the site is far away, the transportation cost for PV system will be a little higher. Therefore, we will consider the individual PV systems to compare with traditional method.

(1) Assumption of an individual PV system

Kerosene lamps and a battery-powered TV correspond to an equivalent electric output of 37W. A specific PV system that can supply this electric output may be 60W PV module systems. Assumption of this 60W PV system are as follows:

①Breakdown of 60W PV system

Unit prices of components, including PV module, of PV systems in 2005 was estimated above. Unit prices of components for 60W PV system are as follows:

Table 8.2-2 Unit prices of components of 60W PV System

Component	Unit price (US$)	Remarks
60W PV module	136	
Charge controller	3.37	12 V, per A.
Battery	0.34	Wet type 12 V, per Ah.

②Costs of PV array structure and installation

The costs of PV array structure and installation can be estimated on the basis of the actual results of procurement in local market as follows:

Table 8.2-3 Costs of PV array structure and installation of 60 W PV system

Item	Cost (US$)	Remarks
PV array structure	10	Iron
Bolts, nuts, washers	3	
Concrete	9	
Cable	27	
Battery box	3	Iron
Installation	13	
Wiring work	1	
Total	66	Material expenses = 52(US$) Labor expenses = 14(US$)

(2) Outline of design of individual 60 W PV systems

PV system generates DC power in daytime and stores this power in a battery. In night, this stored power is used for appliances. It, therefore, is necessary to use a battery and a charge controller that properly controls charging and discharging. The outline of design is as follows:

①Capacity of battery (VA)

Battery capacity = P_{kw} x 1.5 x 3 x 1.25/(0.8 x 0.7 x 0.98) where

P_{kw} : Output of PV module (W)

1.5 : Maximum output equivalent time of use at night on a rainy day

3 : Days of autonomy

1.25 : Margin

0.8 : Capacity drop ratio by atmosphere temperature 0.08 (at 0℃)

0.7 : Depth of discharge

0.98 : Terminal voltage drop of battery

Battery capacity of 60W PV systems is 615Wh. If the terminal voltage is 12V, the battery price will be 615(Wh) / 12(V) x 0.34(US$/Ah) = US$17.

The conditions of calculation are that winter is rainy season in Syria, days of autonomy are three at the most, and atmosphere temperature at the time will be 0 ℃. Under normal conditions, if power consumption is 60W x 3hrs, depth of discharge is about 30% and will not make any problem. Daytime consumption is not included here.

②Charge controller

As for the current of the charge controller, 60W is controlled at 12V. Hence the price of a charge controller is obtained by multiplying current capacity with the unit price; 60(W) / 12(V) x 3.37(US$/A) = US$17.

In calculating the prices of the battery, charge controller and inverter, we assume divisibility of their capacities. However, actually, these components have specific capacities, and the actual prices may be higher than assumption. When the scale of PV system gets larger, the difference in price will get smaller and will not pose any problem in grasping the trends of generating cost.

③Facility cost of 60 W individual PV system

According to the above-mentioned discussions, facility cost of 60W PV system is summarized as follows. The in-house wiring is excluded.

Table 8.2-4 Facility costs for 60 W individual PV system (US$)

Module	Controller	Battery	Transportation	Material	Labor	Total
136	17	17	9	50	17	246

As for transportation cost, PV module, charge controller and battery were assumed to be all imported from Europe and their transportation costs were assumed to be 4% of their prices. As for inland transportation, 1% of the costs of all items including material cost were counted.

(3) Annual cost related to 60W PV systems

Cost breakdown of 60W PV systems was used to calculate the annual cost of PV system as shown in Table 8.2-5. Durable years of the respective components were taken into consideration.

Table 8.2-5 Annual costs related to 60W PV System (US$)

	Fixed cost					Variable Cost	Total
Year	Module	Controller	Battery	Stand, etc	Subtotal		
1	12.9	2.5	4.4	6.1	25.9	2.5	28.4
2	12.9	2.5	4.4	6.1	25.9	2.5	28.4
3	12.9	2.5	4.4	6.1	25.9	2.5	28.4
4	12.9	2.5	4.4	6.1	25.9	2.5	28.4
5	12.9	2.5	4.4	6.1	25.9	2.5	28.4
6	12.9	2.5	4.4	6.1	25.9	2.5	28.4
7	12.9	2.5	4.4	6.1	25.9	2.5	28.4
8	12.9	2.5	4.4	6.1	25.9	2.5	28.4
9	12.9	2.5	4.4	6.1	25.9	2.5	28.4
10	12.9	2.5	4.4	6.1	25.9	2.5	28.4
11	12.9	2.5	4.4	6.1	25.9	2.5	28.4
12	12.9	2.5	4.4	6.1	25.9	2.5	28.4
13	12.9	2.5	4.4	6.1	25.9	2.5	28.4
14	12.9	2.5	4.4	6.1	25.9	2.5	28.4
15	12.9	2.5	4.4	6.1	25.9	2.5	28.4
16	12.9	2.5	4.4	6.1	25.9	2.5	28.4
17	12.9	2.5	4.4	6.1	25.9	2.5	28.4
18	12.9	2.5	4.4	6.1	25.9	2.5	28.4
19	12.9	2.5	4.4	6.1	25.9	2.5	28.4
20	12.9	2.5	4.4	6.1	25.9	2.5	28.4

Notes) 1. Useful lives of components: Module - 20 years. Controller - 10 years. Battery - 5 years. Stand, etc. - 20 years.
2. 1 % of the total construction cost (fixed cost) was appropriated as the variable cost.

Transportation cost was depreciated by apportioning it among the respective components. Variable cost, being 1%, is small when the scale of system is small. It, however, will become appropriate for larger scale system. Variable cost is considered to be about 2% in advanced industrial countries. In Syria, however, it is assumed to be 1% since the labor cost is lower.

Customs duties are normally charged on PV system components imported from Europe. However, as the customs duties of Syria are complicated, and charging of customs duties itself is a domestic issue, the study team consulted with SSRC/HIAST and decided not to consider customs duties. Moreover, it was also assumed that in principle there was no inflation. However, for reference, when the future prospect was considered, inflation rate of 3% per year was considered.

As a result of the above-mentioned discussion, the annual equalized cost related to 60W individual PV system under the interest rate of 6.5% was US$28.4. The cost over 20 years in present value is obtained by multiplying US$28.4 with the coefficient of discounted value and is US$313. As a capacity factor of PV system is 10% (53kWh), the generating cost is US$0.54/kWh.

8.2.4 Economic comparison between kerosene lamp/battery-powered TV and 60W PV system

Cost of PV system so far has been examined only for the outdoor facilities. To compare it with that of kerosene lamps and battery-powered TV, it is necessary to consider the cost of in-house wiring work.

(1) Cost of PV system including in-house wiring

Cost of in-house wiring work is normally covered by the customers and excluded from the scope of the cost. However, as all the costs must be included in comparison this time, in-house wiring is considered here. Cost of in-house wiring was estimated based on actual cost of Fedre PV system, which is smallest scale system for this project.

Table 8.2-6 Cost breakdown of in-house wiring (US$)

Item	Fluorescent lamp	Switch	Plug socket	Electric wire	Distribution board	Total
Equipment	11.2	2.1	0.8	14.1	39.1	36.3
Installation	0.3	0.3	0.1	0.8	0.5	2.0
Total	11.5	2.4	0.9	14.9	39.6	38.3

The useful life of the in-house wiring is considered to be 30 years or over under normal conditions except switches. Hence, it is assumed to be 30 years. The useful life of fluorescent lamps that correspond to kerosene lamps is assumed to be five years. An 18W fluorescent lamp was used for the lamp equivalent to 20W. A 20W fluorescent lamp was also used as the all-night lamp equivalent to 5W. As a 5W fluorescent lamp is for special purpose, it is expensive and is expected to be hard to find a replacement. As TV sets are common to both cases, they are out of the scope of comparison. With these considerations, the cost of PV system including in-house wiring was derived in Table 8.2-7.

The in-house wiring cost includes the costs of light fittings and tubes itself are not included. Two tubes are needed and their unit price is US$1.5/piece. The respective costs are calculated by using their acquisition costs and CRF that are determined by the useful life and the interest rate.

As a result, annual cost of 60W PV system including in-house wiring was determined to be US$32.0. The cost over 20 years was US$353.

Table 8.2-7 Annual cost of 60W PV system including in-house wiring (US$)

Year	PV system cost	Cost of interior wiring work			Total
		Work	Fluorescent lamps	Subtotal	
1	28.4	2.9	0.7	3.6	32.0
2	28.4	2.9	0.7	3.6	32.0
3	28.4	2.9	0.7	3.6	32.0
4	28.4	2.9	0.7	3.6	32.0
5	28.4	2.9	0.7	3.6	32.0
6	28.4	2.9	0.7	3.6	32.0
7	28.4	2.9	0.7	3.6	32.0
8	28.4	2.9	0.7	3.6	32.0
9	28.4	2.9	0.7	3.6	32.0
10	28.4	2.9	0.7	3.6	32.0
11	28.4	2.9	0.7	3.6	32.0
12	28.4	2.9	0.7	3.6	32.0
13	28.4	2.9	0.7	3.6	32.0
14	28.4	2.9	0.7	3.6	32.0
15	28.4	2.9	0.7	3.6	32.0
16	28.4	2.9	0.7	3.6	32.0
17	28.4	2.9	0.7	3.6	32.0
18	28.4	2.9	0.7	3.6	32.0
19	28.4	2.9	0.7	3.6	32.0
20	28.4	2.9	0.7	3.6	32.0

Notes) 1. Useful life of the facilities of the interior wiring work is 30 years.
2. Useful life of the fluorescent lamps is five years.

(2) Economic comparison of two cases

As all the costs of kerosene lamp and battery-powered TV and that of 60W PV systems were compared here in economics. Before doing that, all of costs for both cases are compiled.

①Comparison of costs

Annual cost in the present context is the cost equalized over the useful life at the interest rate of 6.5%. When the coefficient of discounted value is applied to the annual cost of US$32.0, the cost over 20 years, which is US$353 will be obtained.

Table 8.2-8 Cost 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	

②Economic comparison

First, the equivalent energy consumption, which provides the basis of comparison, will be confirmed. In the case of kerosene lamp and battery-powered TV, 20W x 5hr + 5W x 8hr = 140Wh/day is used for lighting, and 12W x 5hr = 60Wh/day is used for TV. Thus 200Wh/day is used totally. On the other hand, as capacity factor of 60W PV system is about 10%, 24hr x 0.1 x 60W = 144Wh/day can be used. This consumption is almost same as that of kerosene lamp and battery-powered TV.

According to the mentioned above condition, 60W PV systems can be an alternative of kerosene lamp and battery-powered TV. Usually, scales for evaluating economies of alternative plans indicates

[benefit (V) – cost (C)] and [benefit (V) / cost (C) – 1].

Hence installation of 60W PV systems will generate the following values:

◎Value of the PV system

- Per year 118.7 – 32.0 = US$86.7 or 118.7/32.0 – 1 = 2.7
- Over 20 years 1,307 – 353 = US$944 or 1,307/353 – 1 = 2.7

In this case, technical progress is taken into consideration for the case of PV system, but not for the case of batteries for TV. In Syria, SSRC/HIAST has been exerting to improve battery production technology. Hence we will assume how the value of PV system will change when the useful life of battery is extended from one year to three years. It is assumed that price of battery will not change.

(3) Case of three years useful life for battery

As a result of extension of the useful life of battery from one year to three years, the fixed cost of lighting and battery TV will decrease from US$32.2 to US$12.3 (= 4 x 0.240335 + 30 x 0.377576).

Table 8.2-9 Cost of two cases (US$)

Case	Annual cost	Cost over 20 years	Remarks
Kerosene lamp Battery-powered TV	111.1	1,224	Useful life of battery is 3 years.
60W PV system	32.0	353	

◎Value of PV system

- Per year 111.1 – 32.0 = US$79.1 or 111.1 / 32.0 – 1 = 2.4
- Over 20 years 1,224 – 353 = US$871

As above results, extension of the useful life has an effect of saving of US$7 (US$118.7(1year) – US$111.1(3years)) in annual cost and 0.3 (2.7(1year) – 2.4(3 years)) in terms of benefit/cost ratio. Therefore, introduction of PV systems in un-electrified villages is expected to have a significant effect on the household economy.

(4) Case of grid extension

In addition to PV system, grid extension and diesel power generation are considered to be alternatives. Grid extension is implemented according to the plan of the Electric Authority. Therefore, realizing the electrification is limited to appeal to the Electric Authority, and residents must wait for extension. On the other hand, there are no actual cases of diesel generation. Hence we will compare economics between grid extension and 60W PV system that is an alternative of traditional lighting and battery-powered TV.

In case of grid extension, first 20kV transmission line is extended. Near village, voltage is dropped from 20kV to 200V by pole transformers. Then 200V distribution lines are extended and power is supplied to each house of village through lead-in wires. It is not certain that how much each household should bear the cost of grid extension. Hence we assume that all the costs of grid extension including lead-in wires should be borne by the Electric Authority, which is widely practiced.

When power supply is started, each customer should bear in-house wiring cost and the electricity fees depending on consumptions. Now, power supply through grid lines is assumed to be benefits and compare with the economics of PV system. In case of power supply through grid lines, the customers can freely consume electricity without any limit. Hence no direct comparison cannot be made with PV systems, because, PV system has limits of power generated. Hence to make comparison we assume that consumption of customers through grid lines is comparable to the output of 60W PV systems. In-house wiring after lead-in wires are not taken into account, because the figures examined above and the electric appliances to be used are common to both cases. In Syria, the system of electricity fees for residence is based on readings of the meter, and unit price is 0.34SP/kWh (US$0.0074/kWh).

Hence the benefit of power supply, which is comparable to that of 60W PV systems is calculated using conventional electricity fees and shown below.

Table 8.2-10 Benefit of grid extension (US$)

Case	Annual cost	Cost over 20 years	Remarks
Benefit of grid extension	3.3	36	
60W PV system	32.0	353	

Annual cost of power supply through grid lines is obtained to sum in-house wiring (US$2.9) as a fixed cost and cost of yearly PV system power generated multiply electricity fees (Result: US$0.4). This corresponds to the benefit of grid lines.

◎Value of the PV system

- Per year 3.3 − 32.0 = △28.7 (US$)
- Over 20 years 36 − 353 = △317 (US$)
- 3.3 / 32 − 1 = △0.89

As the electricity fees are set at very low in Syria, and power supply is supported by the government, therefore, PV system is still expensive when compared with it. However, un-electrified villages in Syria are dispersed in mountainous areas and plains and the numbers of households in such villages are small. Promotion of electrification of such villages in future through grid extension will require large investments in transmission lines and distribution lines. Moreover, it is a fact that realistically, the residents of un-electrified houses have been using kerosene lamp /battery-powered TV as discussed above.

(5) Economic internal rate of return (EIRR)

EIRR normally used as a yardstick for measuring the feasibility of economic realization of a project. This rate of return is defined as follows:

$$\sum_{i=1}^{n} \frac{C_i}{(1+r)^i} = \sum_{i=1}^{n} \frac{B_i}{(1+R)^i}$$

where n : Useful life of system

Ci : Sum of the investment and annual cost over in year i

Bi : Benefit of the project in year i

R : EIRR

It is understood that when this EIRR of a project is 12% or over the World Bank would consider it as an object of its investment. For the Asian Development Bank the rate is 10% or over, and for Japan the rate is 7% or over, respectively.

The cost and the benefit are not measured in market prices but economic prices. As most of components of PV system are imported and customs duties are not considered in its facility cost (including transportation cost), its economic cost may be considered to be the market price. On the other hand, when the benefit to be compared with is kerosene lamp/battery-powered TV; we must consider the performance of batteries. As a performance of present Syrian batteries is low, if we use batteries having a useful life of three years, performance will approximately attain the international level. In the following, EIRR will be examined specifically under this condition.

Table 8.2-11 shows EIRR of the components of 60W PV systems. Costs related to PV system consist of capital costs for each time of investment and the operation and maintenance costs of each year being variable costs. The capital costs consist of the initial investment, costs for replacement of batteries every five years, and replacement of the controller in the 10th year. The benefits of kerosene lamp and battery-powered TV are treated in the same role. However, the useful life of the batteries for TV is three years. Discount rate was selected on a trial-and-error basis to find one that approximately equates the cost and the benefit as shown below:

· Discount rate 65 %	:	Total of costs in present value	153.9
		Total of benefits in present value	159.1
· Discount rate 75 %	:	Total of costs in present value	144.5
		Total of costs in present value	138.8

Accordingly, 159.1 − 153.9 = 5.2 and 138.8 − 144.5 = - 5.7

65 + 5.2 / (5.2 − (- 5.7)) x (75 − 65) = 69.7%

Table 8.2-11 EIRR of 60W PV System (US$)

Year	Cost			Benefit			Present value			Present value		
	Capital cost	Variable cost	Total	Capital cost	Variable cost	Total	Discount rate 65%	Cost	Benefit	Discount rate 75%	Cost	Benefit
1	246	2.5	248.5	34	86.5	120.5	0.060	150.1	73.0	0.571	142.0	68.9
2		2.5	2.5		86.5	86.5	0.367	0.9	31.8	0.327	0.8	28.2
3		2.5	2.5		86.5	86.5	0.223	0.6	19.3	0.187	0.5	16.1
4		2.5	2.5	30	86.5	116.5	0.135	0.3	15.7	0.107	0.3	12.4
5		2.5	2.5		86.5	86.5	0.082	0.2	7.1	0.061	0.2	5.3
6	17	2.5	19.5	4	86.5	90.5	0.050	1.0	4.5	0.035	0.7	3.1
7		2.5	2.5	30	86.5	116.5	0.030	0.1	3.5	0.020	0.1	2.3
8		2.5	2.5		86.5	86.5	0.018	0.1	1.6	0.011	0.0	1.0
9		2.5	2.5		86.5	86.5	0.011	0.0	1.0	0.007	0.0	0.6
10		2.5	2.5	30	86.5	116.5	0.007	0.0	0.8	0.004	0.0	0.4
11	34	2.5	36.5	4	86.5	90.5	0.004	0.2	0.4	0.002	0.1	0.2
12		2.5	2.5		86.5	86.5	0.002	0.0	0.2	0.001	0.0	0.1
13		2.5	2.5	30	86.5	116.5	0.001	0.0	0.2	0.001	0.0	0.1
14		2.5	2.5		86.5	86.5	0.001	0.0	0.1	0.000	0.0	0.0
15		2.5	2.5		86.5	86.5	0.001	0.0	0.1	0.000	0.0	0.0
16	17	2.5	19.5	34	86.5	120.5	0.000	0.0	0.0	0.000	0.0	0.0
17		2.5	2.5		86.5	86.5	0.000	0.0	0.0	0.000	0.0	0.0
18		2.5	2.5		86.5	86.5	0.000	0.0	0.0	0.000	0.0	0.0
19		2.5	2.5	30	86.5	116.5	0.000	0.0	0.0	0.000	0.0	0.0
20		2.5	2.5		86.5	86.5	0.000	0.0	0.0	0.000	0.0	0.0
Total								153.9	159.1		144.5	138.8

EIRR of 60W PV system was as high as 69.7%. PV system naturally deserves adoption.

8.2.5 Summary of economic analysis

Findings of economic analysis of kerosene lamp and battery-powered TV in an un-electrified village and that of 60W PV system were as follows:

①Kerosene lamp and battery-powered TV is not unique in un-electrified villages and general style. Its cost is very expensive when compared with the electricity fees. Hence the residents of such un-electrified villages are forced to bear greater burdens in addition to inferior living environment in comparison with the residents of large cities and farmers who live near cities and use grid line electricity.

②If PV system is used as an alternative, PV system allows the residents to use electricity at one fourth of the cost of kerosene lamp and battery-powered TV. Additionally, recent price drop of PV system is considered.

③EIRR of 60W PV system is as high as about 70% and meets the condition for overseas financing.

④Like wind turbine power generation, PV system is not restraint by geographical conditions and can be used anywhere.

⑤Electrification of un-electrified villages by grid extension will be continued. Its economics, however, will deteriorate extremely because the numbers of households of villages are much smaller and the distances from grid line to such villages get longer than before.

Therefore, introduction of PV systems is a very important task for the Electric Authority.

8.3 Proposal of materials for introduction plan of PV systems

The objective of this project is to introduce a various PV systems in un-electrified villages in Syria, utilize such systems to enhance a livelihood of the villagers.

(1) Electrification with PV systems

①Centralized PV system

- Site : Zarzita (mountains area)
  (Number of household 40, population 376 persons)
  Capacity : AC 220 V 35 kW.

②Individual PV systems

- Site : Fedre (mountains area)
  (Number of household 13, population 81 persons)
  Capacity : DC 12 V 200 W.
- Site : Katoura (mountains area)
  (Number of household 25, population 205 persons)
  Capacity : DC 12 V 300 W.
- Site : Kalif (plain area)
  (Number of household 25, population 168 persons)
  Capacity : AC 220 V 500 W (shared by plural households)

(2) Water pumping/desalination with PV systems

①Water pumping system

- Site : Zarzita (mountains area) (well depth 500 m)
  Capacity : for pumping 1.9 kW x 2, for transferring 0.8 kW,
  Pumping water quantity: 8 m^3/day.

②Water pumping/desalination system

- Site : Kalif (plain area) (well depth 58 m)
  Capacity : for pumping 1.9 kW, for desalination 8.6 kW,
  Water production quantity: 4 m^3/day.

(3) Development of cottage industry

Surplus electricity from the centralized PV system for Zarzita in summer has been utilized to produce cloisonné and stone powder products. They have been sold as souvenirs at St. Simeon Castle.

From the stage of planning and designing of these facilities, the study team has been keeping close contact with SSRC/HIAST. Through various stages of designing, installation and operation of PV systems and water pumping/desalination systems, the study team and SSRC/HIAST have been jointly executing and technology was transferred. About three years have passed since installation of such facilities. During this period, these systems have been operating well without trouble. As for system operation, it has been decided that management of village electrification systems was transferred from SSRC/HIAST to the Electric Authority, and that of water pumping/desalination systems was transferred to the Water Authority. About one year has passed since the transfer of such duties. Through the both Authorities experiences of system management activity, PV system is evaluated as very high reliability. SSRC/HIAST, which is technical leader of Syria, and the Electric Authority and the Water Authority, which are in charge of introduction and promotion of various PV systems in future, have been participating in the above-mentioned demonstrative study. Those organizations are showing keen interests to utilize PV systems and application. Their efforts will contribute much to significant advancement in the expansion of PV system in Syria in future.

One more specific objective of the project is to ensure smooth introduction and utilization of PV systems by the Syrian side and to contribute to promote livelihood of un-electrified villagers in rural areas. To this end, the study team will make economic analysis and case studies to utilize PV systems for un-electrified villages in rural areas. Also, promotion of PV systems is proposed to the government of Syria.

According to the information collected by SSRC/HIAST on PV system technology, the state of development of PV systems has made a significant progress in the advanced industrial countries in the last one year. Therefore, unit prices of components of PV system have shown a trend of sharp decrease. For example, the module prices show such a decrease that the actual price in 2000 was US$4/W whereas the price assumed in the previous year for 2000 was US$5/W. This is expected to be very advantageous to Syria in promoting the introduction of PV system. In view of the situation, SSRC/HIAST requested the study team to review the prices used in the cases examined in the Draft Final Report No.1. In the following, in response to this request, we will reconsider to use this useful information to contribute for expansion of PV system by the Syrian side. Promotion of PV system will be dealt in another chapter.

8.3.1 Outline of plan of PV systems

As for this plan, on the basis of discussion with SSRC/HIAST, it was decided to develop schematic designs of various systems that are desirable in future, and compare their economics with those of alternatives. Thus, the scope of economic feasibility of PV systems is emphasized to make clear. Before developing plans, the study team confirmed the following points with SSRC/HIAST.

- Starting point of the plan is 2005 five years after from now, when the Electric Authority in charge of village electrification and the Water Authority in charge of pumping and desalination will finish to master the related technologies of the systems. During this period, PV system technology itself is expected to develop significantly in the advanced industrial countries.
- At present, the useful life of PV module is considered to be 20 years. We will consider the case of extension of the useful life by ten years, namely, the case of useful life of 30 years.
- Interest rate is set at 6.5%, and no inflation will be considered. However, for reference, a case of an inflation rate of 3% will be considered.
- As customs duties are complicated, they will not be considered. However, imports and inland transportation will be considered.

Under the above-mentioned conditions, the plan to be examined is as follows:

(1) Electrification with PV systems

Regarding the centralized PV system, in Zarzita, system scale is 35kW and standard equipment did not apply for the inverter and controller. Also, distribution network facility is necessary same as the conventional grid. Based on these, including economic analysis, comprehensive study was executed. As a result, large scale centralized PV system is available from technical aspect. However, it is not feasible from the viewpoint of economics. Therefore, for the electrification system, individual PV system such as Fedre and Katoura and mini-centralized PV system like Kalif, which can apply standard product and expect cost down is nominated to study. The individual systems are for isolated and scattered houses. The mini-centralized system has an advantage that its capacity factor will be improved for plural houses that are adjacent to each other. A centralized PV system has been installed in 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 PV system like Zarzita is out of the scope. Specific capacities of the systems considered are as follows:

Individual	: 60W, 120W, 240W, 360W, 480W
Mini-centralized type	: 960W, 2040W, 3000W

These individual and mini-centralized PV systems will be compared in economics with grid extension and diesel power generation. As for the mini-centralized systems, water pumping by surplus power in daytime will be considered as well.

(2) Water pumping with PV systems

Water pumped quantity by PV system is used as a parameter to compare the water cost by PV system with that of diesel generation and examine both economics.

(3) Desalination with PV systems

To keep drinking water for Bedouins in Badia where is the southeast of Hama, desalinated water cost is calculated assuming proper system scale of RO membrane method and ED method.

Desalination of raw waters of various salinity contents will be considered for other areas. Economies of the above-mentioned specific plans will be mainly considered. As for materials and equipment, local procurement is considered as much as possible.

8.3.2 Rural electrification with PV systems

(1) Consideration of system scales for future introduction

The selecting process of PV systems scale for future introduction in Syria and electric appliances and demand to meet selected PV system scale will be outlined. Outline of demand forecast is studied.

①Scales of PV systems

On the basis of actual demonstration, we considered scales of PV systems according to house structures and family configurations in Syria. In Southeast Asia, individual PV system (called Solar Home System (SHS)) such as 50W is used usually to improve the economics of PV systems. Regarding Syrian villages, as their houses are larger and the number of rooms and the number of family members are greater, it was decided to provide five kinds of individual PV systems ranging from

60W to 480W. A specific system will be selected by considering respective conditions.

In mountains and plains there are relatively many cases where plural houses stand adjacent to each other. In such a case, if an AC220V mini-centralized PV system, which can be shared by plural households, is used rather than installing individual PV systems. In this case, capacity factor of PV system will be increased and more efficient. As for the scale, three kinds ranging from 1kW to 3kW were considered.

②Assumption of demands to meet various PV system scale

Theoretically, it would be normal to estimate demands first, then consider system scale that can meet the demands. However, in the case of PV system, if variable scales and demands menus are provided, it will be convenient to customers.

a. Assumption of supply capability

In calculating the monthly supply capability of each PV system, the data of insolation and air temperature collected by the meteorological station in Zarzita were used. The capacity of batteries was calculated based on three days of autonomy in winter. The maximum depth of discharge was assumed to be 70%.

b. Type of power for the respective power systems

- Individual type　　DC 12V
- Mini-centralized type　　AC 200V (single-phase, two-wire 50Hz)

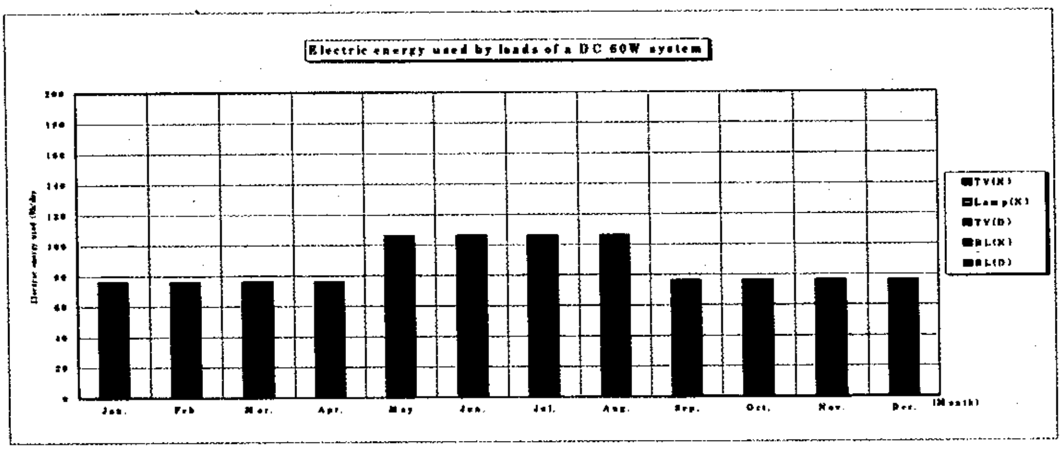
c. Assumption of demands to meet various PV system scale

As for the individual systems, demands were calculated according to kinds of electric appliances and duration of use to meet the respective scales of 60W, 120W, 240W, 360W and 480W. The results are as shown in the following table and diagrams.

Table 8.3-1 Electric appliances to meet individual various PV systems

	System		Applicability
60(W)	10 W fluorescent lamp 24 W TV (black-and white) Radio-cassette-player	: 1 :3(hr)/day : 1 :1(hr)/day : 1 :1(hr)/day	Applicable to houses with 1 to 2 rooms, which account for 50 ~ 70 % of houses in a village.
120(W)	10 W fluorescent lamp 24 W TV (black-and white) Radio-cassette-player	: 3 :3(hr)/day : 1 :1(hr)/day : 1 :1(hr)/day	Applicable to houses with 2 rooms, which account for 10 ~ 30 % of houses in a village.
240(W)	10 W fluorescent lamp 24 W TV (black-and white) Radio-cassette-player	: 4 :3(hr)/day : 1 :3(hr)/day : 1 :2(hr)/day	Applicable to houses with 4 rooms, which account for about 15 % of houses in a village.
360(W)	10 W fluorescent lamp 24 W TV (black-and white) Radio-cassette-player	: 5 :4(hr)/day : 1 :3(hr)/day : 1 :3(hr)/day	Applicable to houses with 5 rooms, which account for less than 10 % of houses in a village.
480(W)	10 W fluorescent lamp 24 W TV (black-and white) Radio-cassette-player	: 5 :4(hr)/day : 1 :3(hr)/day : 1 :3(hr)/day	

1) DC 60 (W) SHS (1 lamp system)



2) DC 120 (W) SHS

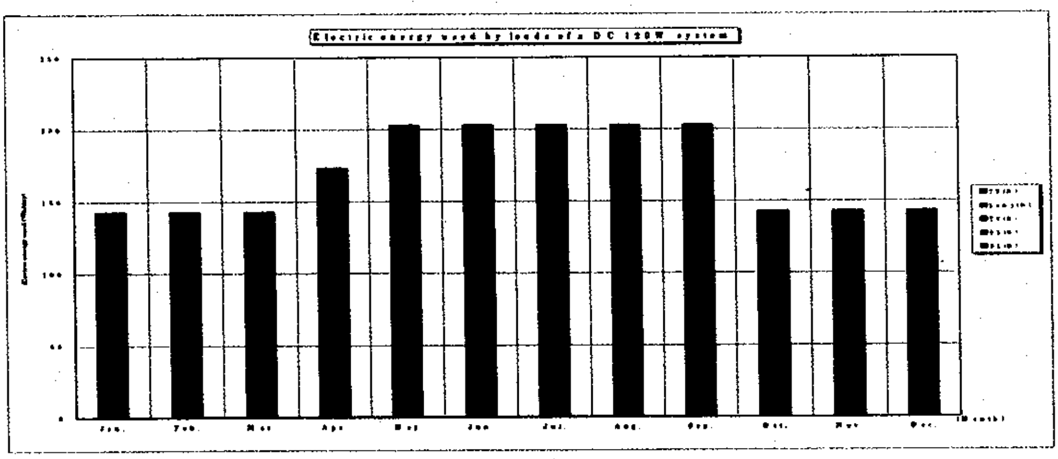
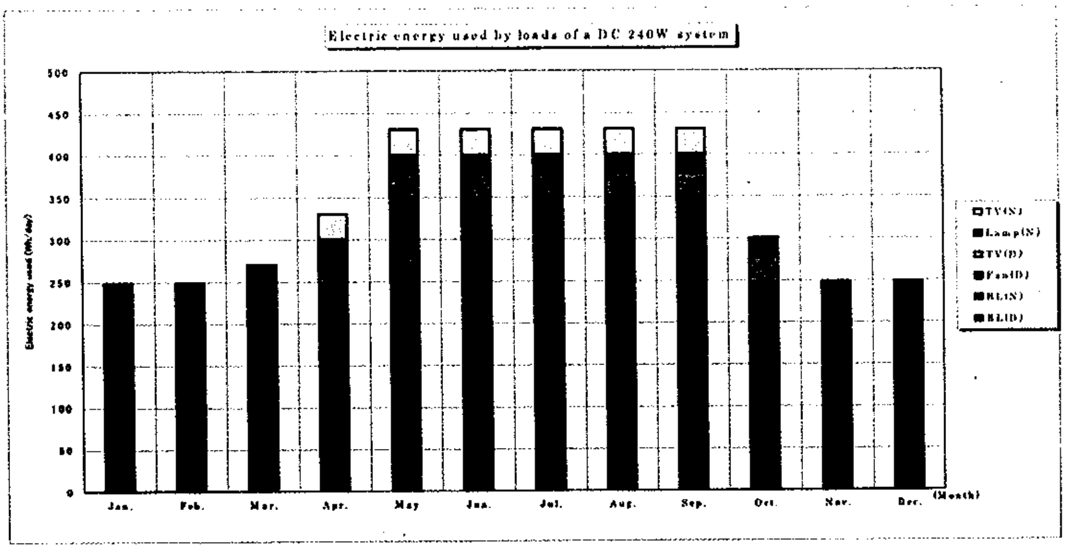
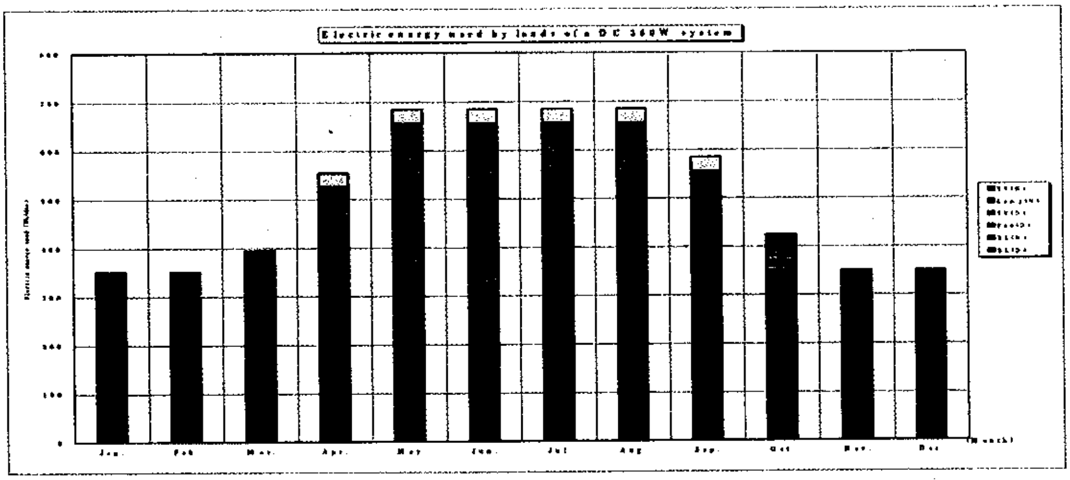


Fig. 8.3-1(1) Assumption of demand

3) DC 240(W) SHS



4) DC 360 (W) SHS



5) DC 480 (W) SHS

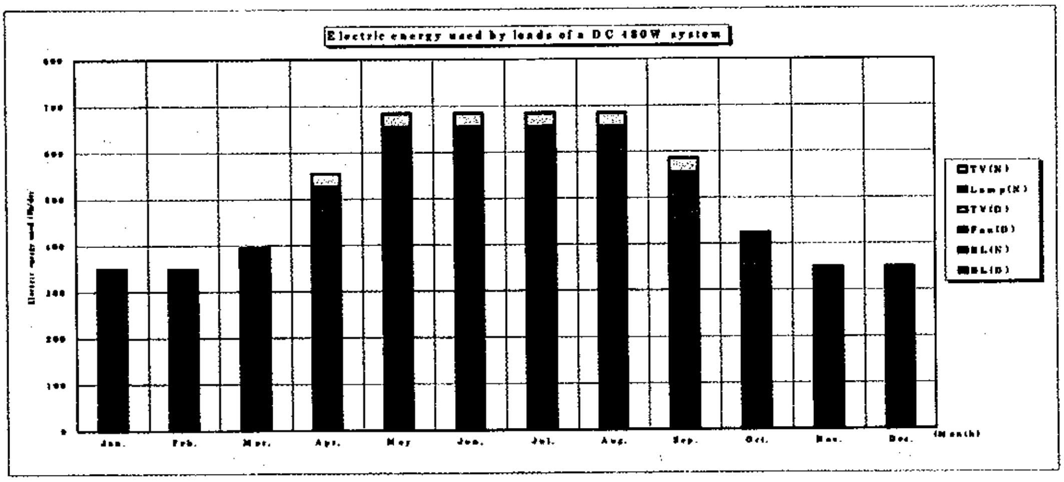
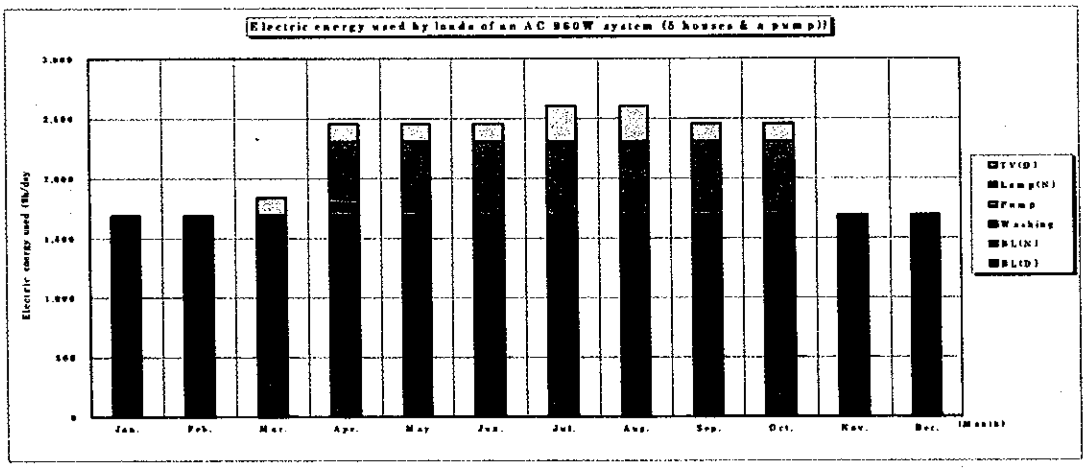


Fig. 8.3-1(2) Assumption of demand

③Assumption of power generated and surplus power by the mini-centralized PV systems (1, 2 and 3kW)

As for the individual PV systems, if the capacity gets larger, the current capacity of charge controller and cable size will get larger. As a result, the price will become relatively expensive. Moreover, there are some limitations on the use of electric appliances. On the other hand, mini-centralized PV systems need inverters but conventional cables can be used because of AC220V. They are less expensive than those for DC. It is more convenient because conventional electric appliances can be available. Moreover, the surplus power generated by the mini-centralized PV systems is greater than that of individual system, thus, this surplus power will be utilized.

1) AC 960 (W) system



2) AC 2,040 (W) system

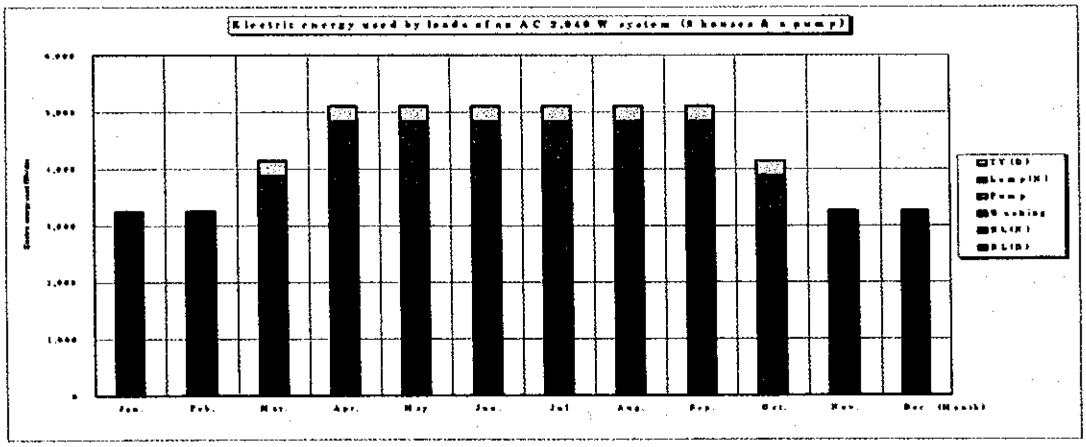


Fig. 8.3-2(1) Assumption of demand for AC Systems

3) AC 3,000 (W) system

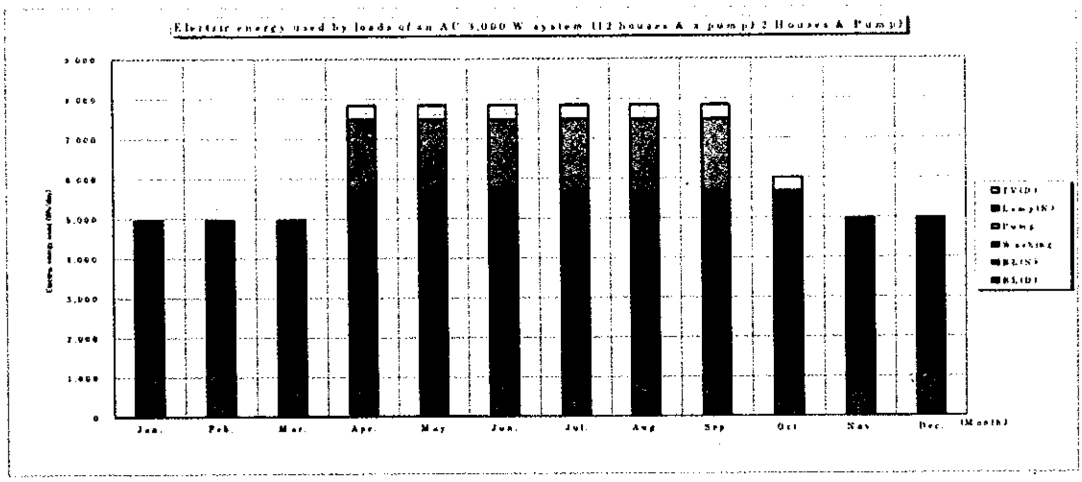


Fig. 8.3-2(2) Assumption of demand for AC Systems

From such a viewpoint, surplus power was estimated to use for water pumping by the mini-centralized PV systems.

(2) Consideration of costs of PV electrification system for future introduction

①Assumption of particulars of PV systems and consideration of generating costs based on such particulars

As mentioned above, the target of start for introduction of PV systems is set at 2005 when the Ministry of Electricity and the Water Authority will master PV system technologies. Systems scales were assumed according to the request of the Syrian side and shown below.

a. Systems assumed

• Individual type	60W, 120W, 240W, 360W, 480W
• Mini-centralized type	960W, 2040W, 3,000W

b. Assumption of particulars for PV systems in 2005

According to the request of SSRC/HIAST, we assumed the particulars of PV systems in 2005 based on documents concerning the latest PV system technology, which were collected by SSRC/HIAST. The findings are described above in "1. State of Development of PV Systems in Advanced Industrial Countries." Here we will use these assumptions to consider the costs of various PV systems that are to be evaluated in future plans. Some essential portions of these assumptions will be outlined below, and other related particulars will be assumed as well.

○Unit price of PV modules

Table 8.3-2 Assumed unit prices of PV modules in 2005

Part no.	Output (W)	Unit price in April 2000 (US$)	Unit price in 2005 (US$)	Remarks
15484	120	492.3	**262.2**	
15483	80	329.5	**175.5**	
15482	60	255.1	135.9	
15481	40	185.9	99.0	

Notes) 1. Ratio of price drop of module in the U.S.A. 0.533/5 years (2.13/4)
2. Shaded assumption was used in the examination.

○Charge controllers

The mean value of the shaded assumption in Table 8.3-3 was used as the unit price of charge controller for 12V.

Table 8.3-3 Assumed unit prices of charge controllers (for 12V)

Part no.	Current (A)	Unit price in April 2000 (US$/A)	Unit price in 2005 (US$/A)	Remarks
32380	8	6.09	**4.26**	0.31
32367	12	4.74	**3.32**	0.30
34966	10	5.02	**3.51**	0.31
34935	20	3.39	**2.38**	0.30

The mean value of shaded assumption of Table 8.3-3 was used as the unit price of charge controller for 24 V.

Table 8.3-4 Assumed unit prices of charge controllers (for 24V)

Part no.	Current (A)	Unit price in April 2000 (US$/A)	Unit price in 2005 (US$/A)	Remarks
34942	10	5.43	**3.80**	0.70
34936	20	3.94	**2.52**	0.70
37002	60	2.99	1.39	0.67
33686	25	4.46	3.12	0.65
33685	35	2.80	1.96	0.65

Note) 1. Remarks indicate ratio of price drop of catalogues (for about 2 years).

○Inverters

The mean value of the shaded assumption of Table 8.3-5, US$0.24, was used as the unit price of inverter.