June 2000 • NREL/SR-520-28601

Subcontractor Report

Ramakrishna Mission Initiative Impact Study

Final Report

A. Chaurey
TERI
New Delhi, India

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

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Contract No. DE-AC36-99-GO10337

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NREL Technical Monitor: J.L. Stone

Prepared under Subcontract No. AAD-0-30604-01

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Contents

List of tables

List of figures

List of organizations and their respective contacts

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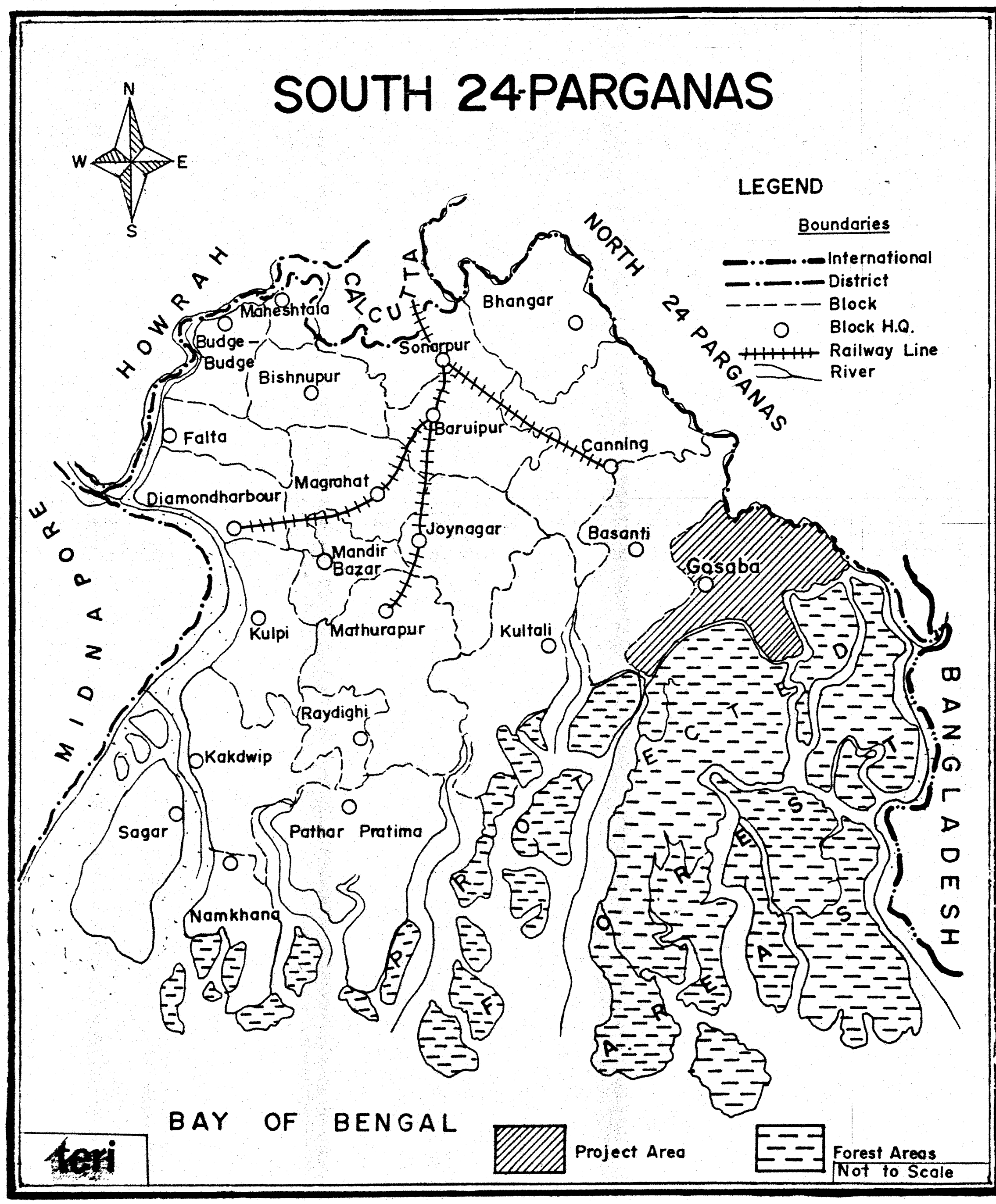

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Sagar
Pathar Pratima
Namkhana
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RESERVED FOREST AREA
BAY OF BENGAL
Project Area
Forest Areas
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Executive Summary

This report has been prepared by TERI for National Renewable Energy Laboratory, US under its contract no. DE-AC36-99G010337. It presents the results of the evaluation and impact assessment of solar photovoltaic lighting systems in the region of Sunderbans, West Bengal, that were deployed by a reputed NGO Rama Krishna Mission under the auspices of INDO-US collaborative project.

The objective of the study were to evaluate the SPV systems for their impact on the individual households as well as on the community, assess the effectiveness of the implementation and financial mechanisms, and to draw a long-term strategy for NREL's activities in Sunderbans based on case studies of similar interventions.

Description of the project

Sunderbans, a part of the vast delta of River Ganga, is characterized by mangrove swamps and islands interwoven by a network of small rivers, waterways, creeks, and tracts. Due to these this geographical features of the region, it is very difficult to extend the grid network to supply power to its population, which traditionally has been depending on kerosene and diesel generating sets for its electricity requirements. With the intervention of the central and state governments, and through the efforts of NGOs such as the Rama Krishna Mission, the island community now has access to electrical power through the use of renewable energy systems. Solar home lighting systems based on photovoltaic technology are deployed in large numbers in individual households for providing power to a couple of light points and a TV set.

In 1996, NREL had planned to implement a project in a selected block (Gosaba) of Sunderbans in collaboration with the Indian Ministry of Non-conventional Energy Sources on an equal fund-sharing basis. Under the project, provision was made to supply 300 DLS (domestic lighting systems) based on 53 Wp module capacity to individual households and a few other systems such as for lighting, medical refrigeration, and pumping water to community centres. Rama Krishna Mission was identified to be the implementing agency and TERI (Tata Energy Research Institute) was given the contract for pre- and post- installation studies. Rama Krishna Mission deployed 290 DLS and all the community centre systems. Remaining 10 DLS were deployed by the WBREDA (West Bengal Renewable Energy Development Agency).

TERI evaluated the systems in 1997 and reported its findings to NREL. However, at the time of the evaluation, the systems at the community centres had not been installed and the DLS had been installed by the households only recently; therefore, the systems had not been operational long enough for proper evaluation. Consequently, it was decided that a complete evaluation and impact study be undertaken in 1999, which should not only survey the households that had been surveyed before (*repeat survey*) and study the effectiveness of community centres systems but also draw a long-term strategy for NREL's future activities based on case studies of similar interventions. The present report is a report of that study.

Performance evaluation and impact assessment of SPV domestic lighting systems

Totally, 152 households were surveyed, out of which 29 had also been a part of the earlier pre-and post-installation surveys, 47 had been a part of the earlier post-installation survey, and 76 were new households which were surveyed for the first time. A set of 46 out of the total 152 households was selected for evaluating the systems for their technical performance with respect to module output, condition of the battery, and daily energy consumption.

Of the total 300 modules, 2 had been stolen; 9 out of the total 300 batteries needed to be replaced, and 10 out of the 300 charge controllers were non-functional. The statistics for the surveyed households indicate 32 luminaire-related faults (blackening or flickering of CFL's) and 11 other faults related to fuse, switches, etc.

The households have found the DLS useful in several ways: the light makes it possible for children to study even after daylight hours, it deters thieves, and the family can watch TV. There is a demand for additional light points or a higher capacity system by 73% of the surveyed households. Due to the increase in family size, 56% households want to purchase additional systems. One of the most significant advantages of DLS, as reported by 93% households, is security against thefts.

Consumption of kerosene, which was the only source of lighting in the households prior to DLS, has been reduced by 7 litres per month on an average. Since the households are now able to meet 50% or more of their demand from the kerosene bought from the Public Distribution System at Rs 3.50 a litre, there is a substantial saving in monetary terms as well. (From Rs 72.3 to 32.64 per month on an average in one of the villages)

Most of the batteries were found to be in good physical condition with respect to casing, battery terminals, and battery boxes. The average daily ampere–hrs received by the batteries is in the range 10–15, whereas the consumption is about 10 ampere–hrs daily. Illumination was inadequate for reading in a few households.

Each DLS customer was expected to pay about 50% of the total cost of the system through a financing scheme (Rs 3500 as a down-payment and Rs 3600 to be paid 60 equal monthly instalments). Payment collection has been 88% till date.

Evaluation of SPV system installed at the community centres

In order to provide benefits to the community at large, and particularly to those who do not have access to DLS, different types of SPV systems were provided to the village youth clubs. These youth clubs are involved in community development through such activities as running libraries, organizing social and cultural festivals, and offering tuition to children of the poor. Depending on the focus, the clubs were given appropriate systems to suit specific objectives, a medical refrigerator and lighting system to health centre, and lighting systems to the weaving-cum-training centres to increase their hours of operation, battery charging stations to provide a better alternative for charging batteries, and a water pump to youth club.

Eight institutions received SPV systems: five youth clubs, two weaving-cum-training centres, and one health centre. The most significant impact of the lighting systems provided to the youth clubs has been on the education of children from the poorer families because members of the youth club provide tuitions to these children at a nominal fee in the evening within the club premises.

In general, the systems have not been used fully on account of the slow development of the institution itself. For example, the health centre frequently faces a situation when the doctor is not present for months together and the SPV lighting system, although functional, is still not able to serve the community.

Of the two battery charging stations, one has been able to sustain its popularity, while the other faces a tough competition from the diesel set charging shops which provide a facility of complete battery service to the customer. With the growing popularity of the gasifier plant in Gosaba, battery charging is fast becoming a household activity where consumers use electricity from the gasifier to install a charger at home and extend this service to their neighbours as well. Rupayan solar battery charging station is the least preferred option in Gosaba.

Study of other initiatives in the region

Several other interventions in the region were studied to get strategic inputs for developing a long-term plan for NREL in the region. The biomas gasifier power plant at Gosaba, a 25-kWp SPV power plant, a private solar shop, Aditya solar shop (run by the Ministry), a comprehensive health project, and battery charging shops using diesel generators were studied for this purpose.

It was observed that while there is a sizable number of households that still need DLS, there is also a growing demand for AC mains electricity, which is being supplied by the gasifier plant and by the 25-kWp SPV plant. There is also a need for an alternative to the diesel generator which currently supplies electricity to shops in the weekly market. Owners of these shops prefer to pay Rs 4-5 a day to the supplier for getting electricity to power a 100 watt bulb for 4-5 hours, rather than invest in thousands of rupees to purchase any type of SPV system.

The case study of the diesel generator charging shops highlighted the preference of customers for these shops because it is a one-stop-shop for all battery-related services. These shops enjoy credibility among the villagers who not only buy batteries or get them serviced but also resell the batteries to these shops.

Long-term strategy

Based on the evaluation of the DLS, the community centre systems, and other interventions in the region, a future plan of activities for NREL has been drawn up focussing on four major issues, which are described below.

1 Improved utilization of available hardware inclusive of DLS, water-pumping system, battery charging stations, and systems at community centres.

It has been shown that within the existing capacity of the DLS, it is possible to provide one more light point, thereby satisfying the additional needs of the households. Further, to continue with the community development work that these centre have been committed to, it is proposed to provide ten more lighting systems through Rupayan with a condition that the existing recipient centres utilize their SPV systems fully and are able to show the same both in quantity and quality. The scheme may be implemented through a business plan with appropriate monitoring indicators and a milestones chart.

As for the battery charging stations, it is suggested that the one at Rupayan be dismantled and its hardware rehabilitated in the form of DLS. Eighty new customers can be given DLS through this activity.

After 24–28 months of rehabilitating the Rupayan station, Chotomollakhali can be rehabilitated in a similar way only if it fails to sustain itself during the period.

2 Utilization of existing funds for future expansion of the DLS programme

The project till now has generated approximately Rs 1.26 million rupees by way of a revolving fund through initial down-payment and the monthly instalments from 290 DLS customers, out of which a small amount has been spent on project management. These funds are kept for providing loan to the DLS customers for replacing their batteries. A sum of Rs 102 850 was collected as maintenance charges, which has been spent, leaving a balance of about Rs 22 000.

The experience shows that the maintenance and management requirements for DLS would be Rs 20 a month for each system. At this rate, a total of Rs 185 600 would be spent on these expenses. If Rs 40 out of the total monthly collection of Rs 60 was contributed towards the revolving fund, an amount of Rs 371 200 would be generated in the remaining 32 months of the project. With 17.5% of the total Rs 1 636 727 that the project would generate as revolving fund, 80 new customers can be partially financed under a similar scheme.

3 Capacity-building and institutional development

The study recommends setting up of a shop-cum-repair centre at Rupayan to service both old and new DLS customers in order to enhance the effectiveness of the supply and by way of after sales service infrastructure.

Further, to enhance the skills of technicians, a refresher training programme as well as an advanced training programme on system design and repair and servicing of electronic components such as charge controllers and inverters is suggested.

Finally, in order to address the problem of high turnover of its skilled staff, the study recommends skill acknowledgement and professional development programmes such as train-the-trainer both within and outside country. An option for technicians to work on turn-key contracts rather than on salary basis might also address the issue.

4 Prospects for new initiatives

Finally, the study recommends two new initiatives in the region, which are as follows.

- setting up of a 25-kWp decentralized power plant for supply of AC electricity. This initiative supplements the efforts of the local government in expanding a popular programme, which has been shown socio-economically and environmentally beneficial.
- Solar lantern charging-cum-renting shops. Five solar lantern charging-cum-renting shops should be set up in each village, with each shop owning a unit to charge 10 lanterns. Initially, ten villages can be identified as beneficiary villages in which these shops can be set up. Charged lanterns can be rented out in the evening for household- and village-level functions.

The study discuses the rationale, system specifications, financing and operational details, and socio-economic and environmental benefits of both the above initiatives. It also recommends the use of a mix of crystalline and thin-film technologies for SPV modules in order to provide an opportunity to evaluate the techno-comercial advantage of the latter in Indian market.

Further, an option has been worked out where existing business entities are involved as partners in the intervention to address the long-term sustenance of the same.

1 Description of the project

1.1 Rural electrification initiative in Sunderbans, West Bengal

Sunderbans literally means "Beautiful Forest". It is a part of the vast delta of the river Ganga, an area characterized by mangrove swamps and islands interwoven by a network of small rivers, waterways, creeks and tracts. It is an abode of famous Royal Bengal Tiger. The wetlands of the Sunderbans play a vital role in flood control. Some of its mangrove species filter water, thus removing sediments and pollutants.

Majority of the population in the Sunderbans is dependent on agriculture and fishing, and on mangrove and forest related sources such as firewood, honey, timber, tannin, charcoal, fruit and fodder. To protect the natural habitat, environment and the bio-diversity of the region, the Sunderbans Biosphere Reserve was established in 1989 covering 8630 sq. km., including about 5366 sq. km. of human habitat along with the entire forest area.[1]

The remote villages and hamlets of the southern part of the Sunderbans suffer from chronic shortage of energy due to non-availability of grid power. It is extremely difficult, if not impossible, to extend high tension transmission lines to these areas as most of the places are separated from the mainland and from each other by wide rivers and creeks.

Since it is highly cost prohibitive to draw transmission lines across very wide rivers and creeks, Solar Photovoltaic System is considered to be the right choice for providing clean energy to these remote settlements. At present, total installed capacity of SPV in Sunderbans is 410 kWp, providing service to a total of 4500 consumers through Domestic Lighting Systems (DLS) and Power Plants. West Bengal Energy Development Agency, which is the state level organization planning and promoting the use of renewable energy technologies (RET) in this state, has set a target of cumulative SPV installations of 2000 kWp by the year 2003.

Complementing the efforts of WBREDA and the MNES, Rama Krishna Mission (RKM), a well-respected humanitarian non-governmental organisation (NGO) with operations worldwide, is concentrating its efforts in this region to promote the use of RETs. Among several programmes on SPV, RKM has successfully deployed over 2000

[1] Courtesy: *Solar Energy in the Sunderbans*, a document published by West Bengal Energy Development Agency, and Ministry of Non-conventional Energy Sources

DLS, and about 450 solar lanterns till the end of the year 1999 [2]. Annexure 1 provides the geographical and meteorological data of The Sunderbans.

1.2 Rama Krishna Mission initiative- Indo-US Collaboration

Under the auspices of a Memorandum of Understanding (MoU) between the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), and India's Ministry of Non-conventional Energy Sources (MNES), a project has been initiated in the Gosaba block of Sunderbans to address the problems of rural electrification and provide a sustainable and replicable solution for the same. Rama Krishna Mission has been chosen to execute the project which involves providing 300 Domestic Lighting Systems (DLS) to individual households and lighting and other SPV systems for Community Centres. The entire project was funded through equal contributions from India and the USA in amounts of US$ 200,000.

1.3 Management of the Project

The MoU calls for 50-50 cost sharing in which the USA provided the PV modules, charge controllers, a water pump and initial training. The Indian government provided the battery, all balance-of-systems and payment of all customs duties for the imported components[3]. Rama Krishna Mission (RKM) is responsible for identifying the recipients of various systems, follow-up training, installation, maintenance and revenue collection.

R K Mission has executed the project through a three-tier structure to ensure the effectiveness of the project implementation. Solar Energy Unit of Lok Shiksha Parishad (LSP)[4] is the apex organization for designing the project. Block level affiliate organization, which are called Self-Governing Cluster Level Organizations is the co-ordinating body for the Youth Clubs. Rupayan, at Gosaba Block which formulated the second-tier in the implementing structure is the selected one for the project. The project implementation is done by grass root level implementing organizations called Self-Governing Village Level Youth Clubs. RKM co-ordinated with a private sector manufacturer M/s Exide Industries to implement the project. (Please refer to the organizational chart)

Tata Energy Research Institute (TERI), an autonomous not-for-profit research organization in New Delhi was contracted by NREL to perform a pre- and post-installation studies to assess the impact of the project in the region.

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[2] Courtesy: Endeavour of Rama Krishna Mission, Narendrapur, towards promotion of solar energy use – Document for public circulation

[3] Stone J.L. et.al. 1998. PV Electrification in India and China: The NREL's Experience in International cooperation. Progress in Photovoltaics: Research and Applications. **6**. 341-356.

[4] LSP is a unit of RKM for integrated rural and urban development. The training wing of LSP with the help of its field wing, is responsible for executing all renewable energy programmes of the Mission.

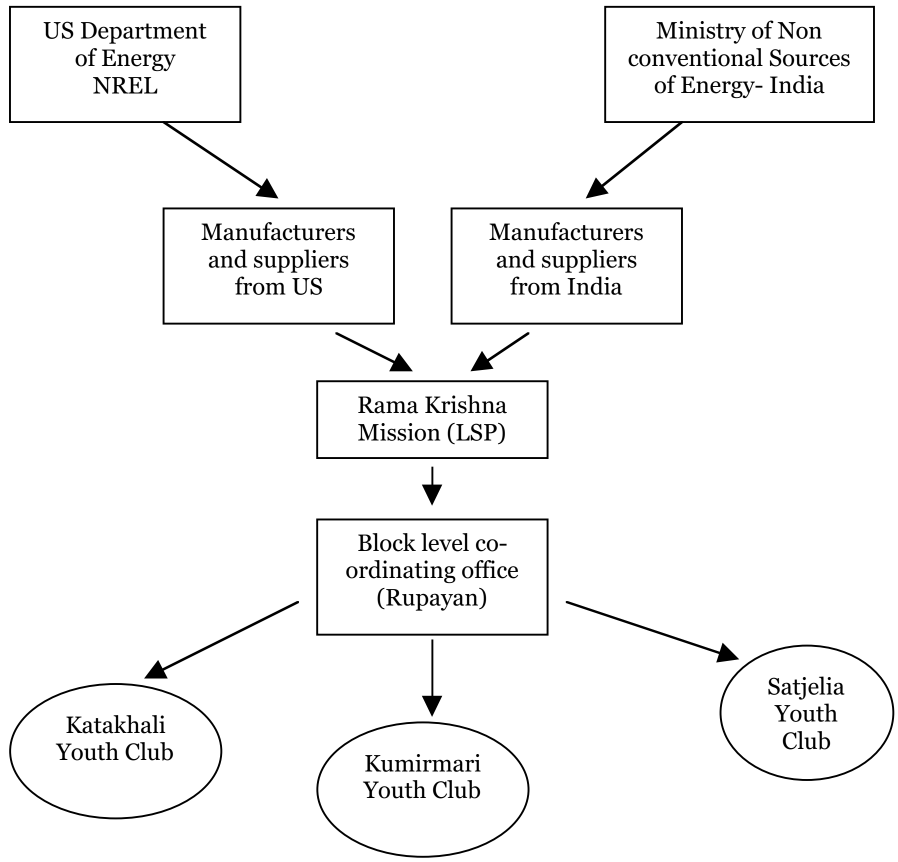

Figure 1. Management of the project

1.4 Photovoltaic systems

The project made provision for 300 DLS, 10 lighting systems for community centre (2 different designs), 2 battery charging stations, 15 street lights, and 1 water pump. Table 1 provides system details.

Table 1. System details

Type of system (institution)	No. installed	Design details	
Domestic Lighting System	290	Module Battery Lights DC outlet Charge controller (Sunsaver-6)	1 x 53 Wp 1 x 60 Ah 2 x 9 W 1 1
Lighting system design 1	6	Modules Battery Lights DC outlet Charge controller (Prostar-30)	2 x 53 Wp 2 x 100 Ah 2 x 11 W 1 1
Lighting system design 2	4	Modules Battery Lights DC outlet Charge controller (Prostar-30)	5 x 53 Wp 4 x 100 Ah 8 x 11 W 2 1
Battery charging system (Gosaba, Chotomollakhali)	2	Modules System Battery Charge controller (Prostar-30)	80 x 53 Wp (8 spare) 1 10
Refrigeration system	1	Modules Battery Refrigerator Charge controller (Prostar-30)	4 x 53 Wp 4 x 100 Ah 1 1
Street Lighting system	15	Modules Battery Lights Charge controller (Tracer)	2 x 53 Wp 1 x 100 Ah 1 1
Water pumping system	1	Modules Inverter Pump unit	16 x 53 Wp 1 1

1.5 Distribution of systems

Rupayan, the block head quarter of Gosaba block was identified as the second-tier institution to implement the project. Further, seven villages were identified as recipients to SPV systems through their respective Youth Clubs (third-tier institutions). Table 2 provides detailed information on location of these systems:

Table 2 System locations

Name of the institution	Profile of the institution/location	Installed SPV system
Katakhali Vivekanand Seva Mandir	Youth club/ Katakhali	Lighting system design Domestic Lighting Systems
Satjelia Vivakanand Milan Sangh	Youth club/ Satjelia	Lighting system design Street lights Domestic Lighting Systems
Kumirmari Swamiji Sangh	Youth club/ Kumirmari	Lighting system design Domestic Lighting Systems
Chotomollakhali Naba Sakti Club	Youth club/ Chotomollakhali	Battery charging station Lighting system design Street lights
Shantigachi Nari Mongal Samity	Weaving and training centre / Shantigachi	Lighting system design
Pakhirala Weaving Centre	Weaving and training centre/ Pakhirala	Lighting system design
Satyanarayanpur Health Centre	Health centre/ Satyanarayanpur	Lighting system design Street lights Refrigeration unit
Gosaba Rupayan	Youth club (Block coordinating office of RKM)/ Gosaba	Battery charging station Water pump Lighting system design Lighting system design Street lights

1.6 Financial arrangement

The supply of SPV modules and charge controllers was coordinated by the NREL. These two components accounted for 50% of the total project cost. MNES provided 37.5% of the funding while WBREDA contributed another 12.5%.

Systems for institutions such as Youth Clubs were covered completely under the project. Of the total cost of Rs 14 000 per DLS, customers paid a total of Rs 7 100 towards its purchase. The payment schedule included an initial payment of Rs 3 500 and monthly installment of Rs 60 for a period of five years (60 installments). Out of the total collection of Rs 60 per month per system, Rs 45 go towards revolving fund which is generated for providing loan to the customers for replacing their batteries, and for any other similar requirement. The remaining Rs 15 are spent on actual maintenance (Rs 10) and incentive for payment collection (Rs 5).

1.7 Operation, maintenance and revenue collection

At the onset of the project, NREL had conducted a training programme for the RKM technicians on system installation, and their maintenance. Of these trained technicians, two were attached to Rupayan to undertake installation and major repair/ replacement jobs. One technician each was assigned for three village Youth Clubs which were the recipients of DLS. This technician, in addition to looking after routine maintenance of the systems such as battery topping-up, loose connections, switch mal-function etc., was also entrusted with the responsibility of monthly payment collection.

At the LSP, Narendrapur level, the project is supported by a team of skilled technicians who are trained at undertaking all installation, maintenance and repair jobs on different types of SPV systems.

Youth Club maintains a log book to check the performance of the systems and the complaint record. It also keeps records for payment collection on individual user basis. Detailed records are kept at Rupayan, which are sent to LSP Narendrapur regularly.

1.8 Summary of findings of previous study

As a part of the planning exercise for the project in the year 1996, TERI, as an independent organization, was contracted by NREL to conduct pre-and-post project implementation work of household survey and socio-economic impact assessment. The scope of the study included evaluation of the implementation process of the project and the role of different agencies in the same. Subsequently, in December 1996, and again in December 1997, TERI team conducted the pre- and –post installations studies respectively.

Due to an overall delay in the implementation process of the project,[5] the post installation study conducted in December 1997, could not assess the impact effectively as the total usage period of these systems was very short. In addition, systems in the Youth Clubs were not yet installed. However, the study presented the details of the geographic and demographic survey of the target villages and helped Rupayan in identifying individual beneficiaries in three select villages and studying their socio-economic profile. Table 3 presents the summary of key findings of TERI's first two studies, a joint report of which was submitted to NREL in 1998. (TERI Report No. 96/RE/56 (1998)).

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[5] The first batch of systems was installed in February 1997. Installation of the last batch was completed in September 1997.

Table 3 Summary of findings of TERI's previous studies

Scope of study	Findings		
Socio-economic profile of beneficiaries	Katakhali	Kumirmari	Satjelia
Percentage occupation (%) Agriculture: Business:	 30 48	 81 15	 37 29
Percentage of beneficiaries belonging to lower castes	24	94	68
Means of lighting Hurricane lantern Kerosene lamps	 85 20	 95 10	 95 25
Lighting expenditure on kerosene (Rs/month)	47	54	63
Kerosene consumption per household (litres/month)–	9	10	12
Disadvantages of kerosene lighting devices as perceived by the user	Soot deposit (40%), Insufficient lighting (20%), Fire hazards (20%), Health problems (5%)		
Perceived benefits of SPV system	Better light output (50%), Economic benefits (15%), Able to watch TV (12%), Improvement in study environment (8%)		
Motivation to buy SPV system	Education (85%), TV (40%), Better light (100%), Problem of kerosene (18%)		

1.9 Introduction to the current study

NREL, under a separate contract no. DE-AC36-99G010337, awarded a contract to TERI in December 1999 to conduct the post-installation evaluation of DLS users, beneficiary institutions, and a study of other interventions in the region, to propose a long-term strategy to NREL for initiating new activities.

The objective of the current study was to assess the system performance and the effectiveness of the implementation and financial mechanisms in the project. The systems have now been in use for over two years.

1.9.1 Scope of study

Task 1 Evaluation of solar photovoltaic systems

The evaluation study was subdivided into two components; namely repeat evaluation of households where DLS have been installed and evaluation of solar photovoltaic systems installed at the village institutions

Repeat evaluation

Repeat evaluation was taken-up in households that were covered during the earlier project evaluation. The following aspects were studied:

- State of the equipment and satisfaction of the users
- Impact of the lighting systems
- Effectiveness of the implementation, financial, and repair and maintenance infrastructure
- End-users knowledge about system operation
- Energy needs and long-term view of the users
- State of charging and discharging of batteries at the household level.

Evaluation of solar photovoltaic systems installed at village institutions

Lighting systems have been installed at Rupayan (the cluster organisation), village youth clubs (Satjelia, Kathakali and Kumirmari), weaving centres and training cum production centre, and health centre. In addition, two battery charging units and a PV pump have also been installed. The evaluation study assessed to what extent these institutions have been able to meet the said objectives, which were to facilitate various activities of these institutions and initiate new ones for the overall benefit of the community, particularly those who do not have an access to individual SPV systems to their houses.

Specifically, the objectives set by these institutions were:

At Village youth clubs and Rupayan- to initiate night schools, operate library for members and give opportunity to school children to study in club premises in the evening

Weaving Centre and Training -cum- production centre- to have an evening shift, thus providing opportunities to women members to work in additional shifts

Health centre- to assess how the lighting system has helped in better management of its day-to-day operation which were earlier carried out with the help of the kerosene lighting devices. Also, the utilization of refrigerator in storing vital drugs and vaccines particularly for snake bites.

Battery charging stations- to analyse their management and operation, end-user satisfaction or dissatisfaction and recommendations for improvement. The households in the region largely use batteries either to operate lighting devices or TV. Charging of these batteries is a difficult process and the users are either dependent upon the local DG set operators or transport them to the nearest town which has grid electricity. Battery charging stations have been an innovative concept in this region and the study was to evaluate their acceptance and success.

Task II Long term strategy for NREL

The demand of better lighting systems is very high in this region. It has also been found that awareness about solar photovoltaic systems is very high among the non-users of the systems. No large-scale interventions have been tried out in the region, and a need was felt to identify the requirements of potential users and also certain productive applications for which solar photovoltaic system can be used. The objective of the study was to develop a long-term plan for initiating new activities by NREL and local institutions like R K Mission. The following aspects were studied to prepare the plan.

- Identification of energy needs and long terms requirements of the current user
- Identification of successful intervention carried out under the INDO-US project and also other interventions
- Identification of niche area applications and technology, sources of procurement
- Developing an institutional mechanism (with the help of discussion with R K Mission and other agencies like WBREDA, MNES, etc.)
- Costing and economic assessment of the proposed set of interventions

1.9.2 Methodology

Table 4 Summary of methodology

Task	Sample size	Target group	Study tools
Repeat evaluation	150 house-holds	Households having DLS	▪ Structured questionnaire ▪ Physical verification and visual inspection
Evaluation of SPV systems at institutions	8 village institution	▪ Individual beneficiaries of the institution ▪ Management of the institution ▪ Village community	▪ Community meetings for gathering the views of the community, and for sharing information ▪ Focus group discussions aided by discussion guide with open-ended questions on issues of concern ▪ Interviews, aided by interview guide ▪ Physical verification and visual inspection ▪ Case study based on each type of system
Long term strategy	--	▪ RKM, Narendrapur ▪ Rupayan ▪ WBREDA ▪ MNES ▪ Other initiatives in the area	▪ Interactive approach with a strong element of oral and informal communication ▪ Discussions and meetings ▪ Case study of select initiatives

1. Main issues and related Parameters

Main Issue	Parameters to be studied
State of the equipment and satisfaction of the user	▪ PV modules-physical condition ▪ Batteries- average lifetime, specific gravity measurements ▪ Charging and discharging of the battery ▪ Nature and frequency of system failure ▪ Seasonal trends in system performance ▪ Performance of charge regulator ▪ Wiring- condition, if extra wiring has been used ▪ Arrangement during rainy season ▪ Adaptations of the user's electricity needs to the availability of the system ▪ Changes in the set of appliances over time ▪ Other alterations to the original system configuration ▪ Daily load pattern
Impact of SPV systems	▪ Health ▪ Children education ▪ Ease in daily chores ▪ Extra income generation ▪ Savings on kerosene and other lighting options ▪ Perceived need for more electricity
Effectiveness of implementation, financial, repair and maintenance model	▪ Supply network ▪ Time taken to install the system ▪ After sales service network and its functioning ▪ How are the trainers doing ▪ Requirement for refresher training, service centres ▪ Inventory of spares ▪ End-users knowledge about system operation ▪ History and current pattern of payments
Village youth clubs	▪ Night schools ▪ Library ▪ Study in club premises in the evening
Weaving centres	Additional economic benefits due to evening shift
Health Centres	▪ Better management due to lighting ▪ Storage of vital drugs particularly for snake bites
Battery charging station	▪ Overall utilization of the facility and its management ▪ Operation and Maintenance ▪ End-user satisfaction ▪ Improvement in design
Long term strategy	▪ Additional energy needs ▪ Replacement of components like charge controller, luminaires, battery ▪ Other interventions in the area ▪ State and central level planning for future ▪ Status of other similar initiatives (old and new) ▪ Cost-benefit of existing systems ▪ Other options for electricity supply

2. Technical evaluation with respect to charging and discharging of batteries

Sample size

Battery charging stations at both the villages will be studied.
About 20-30% of the total households will be studied.

Parameters to be studied for battery charging station

- Visual inspection for overall condition of batteries
- No. of batteries being charged in a day/ week
- Frequency of charge of the same battery
- Time of placing the battery on charging
- Time of removing the battery from charging
- Specific gravity at the beginning and at the end of charging cycle
- Time at the beginning and at the end of discharge of battery
- Specific gravity at the beginning and at the end of discharging cycle
- History of low voltage discharge

1.10 Structure of the report

The remaining part of the report is presented in 4 chapters as follows:

Chapter 2: Evaluation and impact assessment of SPV Domestic Lighting Systems

The chapter discusses survey details of households, which have been using DLS for almost two years. Some of the households were common in previous surveys, which were conducted in the years 1996 and 1997.

Chapter 3: Evaluation of SPV systems at village institutions

This chapter presents evaluation of SPV systems that were installed at selected youth clubs that are involved in various community development activities.

Chapter 4: Study of other initiatives in the region

This chapter presents the study of similar initiatives in the region other than the NREL ones. Study of these initiatives has provided inputs for preparing a long-term strategy for NREL for planning future interventions in this region.

Chapter 5: Long term strategy

The chapter draws a long-term strategy for NREL to plan future activities in this region based on the evaluation of DLS users and case studies of other interventions.

2 Evaluation and impact assessment of SPV domestic lighting systems

The chapter discusses survey details of households which have been using DLS for almost two years. Some of the households were common in previous surveys which were conducted in the years 1996 and 1997. Details are provided on physical condition of systems, assessment of their impact on users, and effectiveness of supply and after sales service. Results are also presented on technical evaluation of selected systems with respect to the module output, battery charging patterns, condition of batteries, and average consumption of energy.

Figure 2. Proud owners of DLS in Village Kumirmari

2.1 Survey of PV domestic lighting system users

2.1.1 Survey details

Survey of 152 PV domestic lighting system users are as under:

Repeat with previous post installation and pre-installation surveys	29
Repeat with previous post installation survey	47
Non-repeat	76
Technical evaluation	46

Of the total 300 domestic lighting systems (DLS) installed under the project, 290 have been installed in three villages namely Katakhali (Gosaba) (90), Kumirmari (100) and Satjelia (100). Ten DLS have been installed at Tagore Society Mahila Samiti at Rangabelia, which is a residential training-cum-production centre for handwoven fabric and finished items. It also has a shop in its premises where the products are sold. These systems have been installed and maintained by West Bengal Renewable Energy Development Agency (WBREDA). All the other systems are installed and maintained by Rama Krishna Mission (RKM) through its affiliate organization Rupayan, located at Gosaba.

The first system by RKM was installed in village Katakhali on January 31, 1997. The 290th system was installed in village Satjelia on October 4, 1997. It has been reported that modules from two DLS have been stolen from the houses of their respective owners. Remaining 288 systems along with modules are in place. Following is the status of equipment as reported by Rupayan. (Table 5)

Table 5 Status of equipment

Component	Total no.	With RKM	With WBREDA	Remarks
Modules	300	288	10	2 stolen
Batteries	300	288	10	2 have been removed from the site as they are awaiting replacement
Charge Controllers	300	288	10	2 non-functional
Luminaires	600	580	20	

A total of 152 out of the 290 systems installed by RKM were surveyed through structured questionnaire. Although the questionnaire was not administered specifically to the woman of the household, in about 40 % of the case, the respondents were women. This is attributed to the fact that in the current harvesting season, men were busy in their respective fields.

Ten systems at Mahila Samiti Rangabelia were studied through group discussion with participants from women residents, trainees, trainers and office bearers. (Break-up given in Table 6)

Table 6 Break-up of households surveyed in S3* for DLS

Village	No. of systems installed	No. of systems studied	Repeat survey with S1 & S2	Repeat survey with S2	Non- Repeat survey
Katakhali	90	49	10	17	22
Kumirmari	100	52	8	15	29
Satjelia	100	51	11	15	25
Total	**290**	**152**	**29**	**47**	**76**

*Note: S1 Pre installation survey undertaken in December 1996 S2- Post installation survey undertaken in December 1997 S3- Post installation survey undertaken in December 1999

As a part of the above survey, technical evaluation was undertaken for 46 systems selected as under:

21 in Katakhali

10 in Kumirmari

15 in Satjelia

2.1.2 Physical condition of systems

- Out of 152 systems surveyed, 149 were found to be in use. In one household the module was stolen 15 days before the survey was undertaken. The system was in use till it was stolen. Two systems were without the battery and hence were not being used. Batteries were sent to Narendrapur for free replacement under the warranty period by Exide.
- All, except 5 charge controllers, were functioning well. In one of the systems, charge controller has been bypassed due to its total failure. Four charge controllers are partially functional with problems being faced in indicators.
- All the surveyed batteries were found to be in good condition with respect to their terminals, casing and wire connections.[1]
- In five houses belonging to one single village, lux level directly under the luminaire was found to be inadequate for reading purposes[2]

2.1.3 Satisfaction of users

- Generally, all 152 users were satisfied with the services of the technology, i.e. provision of light and power for TV in a reliable manner. At present, 74% of the households are the owners of TV, which has been made possible due to the availability of power through DLS. A total of 68 households have purchased TV after acquiring DLS; 45 households already had one. (*S 2 survey indicated that 54% households had TV. It is to be noted that at the time of S2, the systems were very recently installed and their benefits or the impact was nor clearly felt. However, the survey had indicated that ability to watch TV was one of the motivations to buy the DLS*).
- Further, 73% of the users reported that the current size of the DLS is

Figure 3 Family at work under DLS in Gosaba

[1] A common grading system for batteries is used which is presented in section 2.5.
[2] Illuminance readings using a lux meter were taken for 46 households where technical evaluation of systems was done

inadequate for them and they want higher capacity system.[3] While 56% of the users have demanded additional system as their requirement has increased either due to extension in the house or addition in the family. A total of 56 households have a need for extra lights, 6 have for entertainment and 11 have demanded fan to be powered by DLS

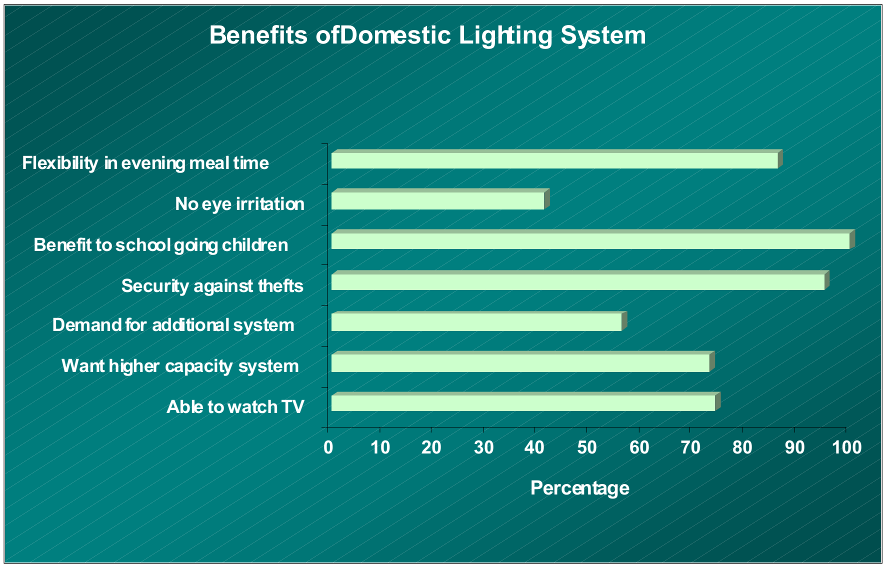

Figure 4 Benefits of domestic lighting system

- Households and shops in Gosaba (belonging to Katakhali main village) now have an access to AC electricity from the WBREDA biomass gasifier power plant. Four DLS owners surveyed in Gosaba have taken the connection from the gasifier plant and are the users of AC electricity as well. These households still use their DLS with satisfaction for watching TV in the daytime, and again used by children at night for studying after the gasifier plant is shut-off. It is to be noted that at present, the gasifier plant operates between 5-11 P.M. every day. The gasifier plant that was commissioned in January 1997, has 450 consumers as on date. Most of these consumers are shops in the market place. The transmission and distribution network of the plant has not yet reached the households that are away from the main street. Considering the slow progress of the gasifier project *(growth depends on the availability of government funds*), and the fact that there are currently not many users to justify the operation of the plant in the second shift for the daytime operation, the utilization of DLS will not be affected.

[3] As presented in the section 2.5, these systems are underutilized currently. Provision for extra light can be made within the existing design of the system

2.2 Impact assessment

- Impact has been studied with respect to the following variables: education of school children, entertainment and other socio-cultural benefits, health and impact on women, and economic benefits.
- In almost all the households, schoolchildren and college students now study under the DLS. It is one of the most important advantages of DLS as kerosene was the only option for this purpose prior to the installation of DLS. Children are able to study for longer hours because of the brighter light.
- Another important advantage of DLS is the security against thefts as reported by 93% households.
- Most of the households reported the benefits of DLS with respect to enhanced light intensity and hence, less strain on eyes particularly while studying. However, benefits such as no eye-irritation, no coughing etc. are not clearly perceived by them as they still use kerosene lamps and, are used to working with its drawbacks. Answers to such questions required some prompting.
- Although there is no direct benefit perceived by the women except overall benefit from the improved quality of light in the house, the survey indicated a large number of girls who are now studying under the DLS in their respective houses. Fifty-six girl children were found to be beneficiaries of DLS.
- As was reported earlier in S2, none of the households have installed lumin-aires in their kitchens. In few cases, it is installed in the varandah outside the kitchen that receives only diffuse light of the lamp. The common reason is fear of attracting insects inside the kitchen and soot deposit on the glass cover of the luminaire.
- There is an average of 7 litres of saving in the kerosene consumption per households per month on lighting due to the use of DLS[4]. Consumption has come down from an average of 10.33 litres per household per month as reported in S1 survey, to 3.3 litres as found during the S3 survey. Since the households are now able to meet 50% or more of their demand from the kerosene bought from the Public Distribution System (PDS) at Rs 3.50 per litre,[5] there is a substantial saving in rupees as presented in table 3 below. The price of kerosene in the open market is Rs10-12 per litre.

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[4] The average saving in kerosene is calculated as the difference between the average consumption per household found in S1 and as reported in S3

[5] Households across the entire survey region get an average of 2 litre per month from PDS @ Rs 3.50 per litre. This rate is however inflated to upto Rs 4 per litre in some villages by adding transportation costs etc.

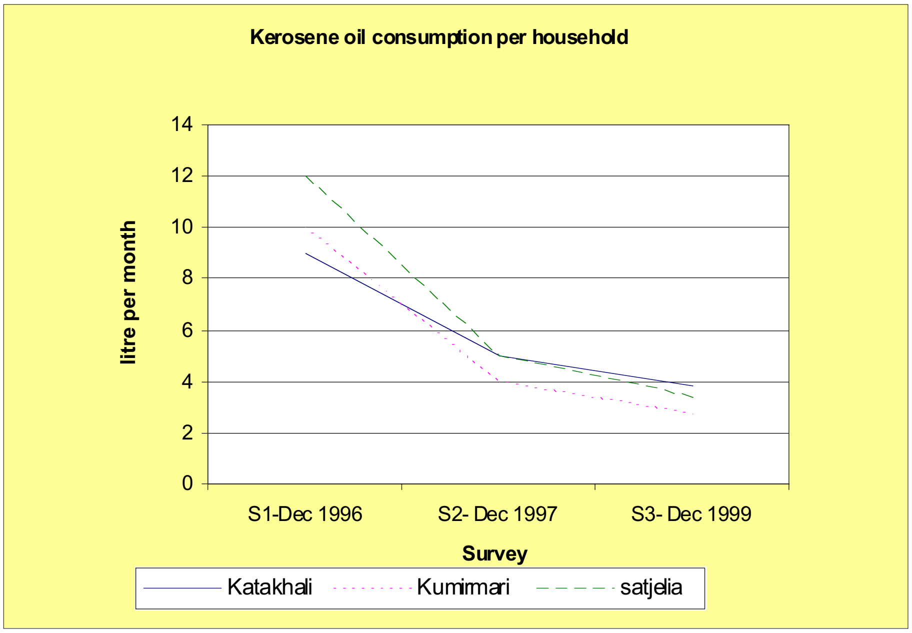

Figure 5 Kerosene consumption per household

Table 7 Fuel consumption and expenditure on lighting

	Katakhali			*Kumirmari*			*Satjelia*		
	S1	*S2*	*S3*	*S1*	*S2*	*S3*	*S1*	*S2*	*S3*
Kerosene oil consumption per household (litre/month)	9	5	3.8	10	4	2.7	12	5	3.4
Kerosene oil consumption per capita (litre/month)	1.6	1.0	0.49	1.7	0.7	0.53	2.0	0.8	0.66
Expenditure on kerosene for lighting (in 1999 rupees)	47	27	25.4	54	20	17.1	63	23	26
	53.9	**27.8**	**25.4**	**61.9**	**20.6**	**17.1**	**72.3**	**32.6**	**26**

Other than the savings on kerosene for lighting at domestic level, the DLS has been found useful for the following professionals. However none of them could quantify the direct financial benefits due to DLS:

- Goldsmith
- Tailor
- Doctor
- Tutor
- Stage artists

2.3 Effectiveness of supply and after sales service

Table 8 gives the details of the faults- nature and frequency of occurrence

Table 8 Nature and frequency of occurrence of faults as reported by 152 survey households

Fault type		Frequency of occurrence			
		Katkhali	Kumirmari	Satjelia	Total
Battery	One cell damaged	2			2
Luminaire	CFL blackening	-	-	9	9
	CFL flickering	4	6	12	22
	Replaced	-	1	-	1
Charge controllers	Mal function	2	1	2	5
Others	Short circuit, loose connection, switch, fuse	3	2	6	11

Table 9 Nature and frequency of occurrence of faults for 290 DLS as recorded at Rupayan

Fault	Occurrence	Record of repair	Remarks
Battery- one cell damaged	12	9 have been replaced by Exide under warranty period	3 are yet to be replaced.
Charge controller	10	8 have been replaced by RKM from the spare stocks	2 systems have bypassed the CC and have made direct connections
Luminaire-CFLbulb	39	39 have been replaced by Exide under warranty period	
Luminaire-inverter	15	14 have been replaced by Exide under warranty period	1 luminaire inverter is yet to be replaced.

- RKM has developed a format for *Monthly Maintenance Record* which records name of the beneficiary, date of installation, module no., voltage of battery, specific gravity of battery, Voc of module, Isc of module, load current and signature of the beneficiary. The recording however has not yet been started.
- Since the systems were under the two year guarantee by Exide, most of the replacements were prompt and without any costs to the users The guarantee period was over in October 1999. The survey indicated that users are willing to pay for the cost of the spare (roughly it is Rs 100 for either changing the CFL bulb or the inverter in the luminaire, the two most commonly occurring faults). However it would be worth the effort to see how many users are getting their systems repaired if the frequency of occurrence of fault continues to be so high.

- RKM has been facing an acute problem with high turnover of its trained technicians and engineers. Of the total 10 persons (9 technicians + 1 engineer) that were trained under this project, 4 have left the organization. For the project, there is one deputed technician per village (total of 3 technicians) for regular maintenance and payment collection for an average of 100 households. At the time of the survey, Kumirmari did not have a trained technician. The other two employed technicians are not from the batch that was trained under the project. Apart from these technicians, there is only one service engineer at Narendrapur, who is responsible for servicing all 290 systems spread over three main and several sub-villages. RKM has planned to post one engineer at Rupayan for providing service to 290 systems.
- As on December 1999, payment collection on this project has been 88%. Record of Kumirmari is the poorest. This is mainly due to manpower problem. In both Satjelia and Katakhali, there are deputed technicians who are able to attend to the minor faults. The technician in Satjelia has a radio repair shop and enjoys a good credibility in the village. No technician is present at Kumirmari. Additionally, on account of the distance from Rupayan, fault reporting as well as attending is not very efficient. Since payment collection is dependent on the satisfaction of the user, Kumirmari has the poorest record.

Table 10 Summary of payment collection as on December 1999

Village	Month of last installation in the village	Total no. of monthly installments due	Payment record
Katakhali	June 1997	29	92%
Satjelia	July 1997	28	91%
Kumirmari	August 1997	27	82%

2.4 Evaluation of 29 repeat DLS users

Following are the survey results of 29 households which were surveyed during December 1996, before the systems were installed, in December 1997, and again in December 1999.

Table 11 gives fuel consumption and expenditure on lighting in these houses.

Table 11 Fuel consumption and expenditure on lighting based on 29 households common during S1 and S3

	Katakhali		Kumirmari		Satjelia	
	S1	S3	S1	S3	S1	S3
Kerosene oil consumption per household (litre/month)	9	3.25	10	4.63*	12	4.14
Kerosene oil consumption per capita (litre/month)	1.6	0.57	1.7	0.79	2.0	0.84
Expenditure on kerosene for lighting (in 1999 rupees)	47	27.8	54	40.12	63	32.64
	53.9	27.8	61.9	40.12	72.3	32.64

* Of the total 8 households in Kumirmari, 2 households have a substantial increase in their consumption of kerosene for lighting due to expansion in the family size and starting of a business by the son. Per capita consumption remains almost same as that in S2.

- During S1, there were only 7 households which had a TV, now the number has increased to 24. These households watch TV on an average 3.7 hrs. per day
- A total of 27 households find DLS useful in their children education. In 9 households, girl-child benefits from the DLS in her education
- Fifteen (15) households have reported no eye irritation, while 8 have reported no coughing when compared with kerosene based devices
- Nine (9) households have admitted to DLS enhancing their social status, symbolising a higher standard of living, while 27 have felt a security against thefts due to DLS
- All 29 have found DLS to be a cheaper option to use as compared to the usage of kerosene lamps daily
- Out of 29, 13 are willing to purchase second system if it is available under a similar scheme as the original one. Eleven (11) indicated need for extra light point
- Over a time span of 2 years that these systems have been in use, a total of 5 CFL bulbs have been replaced, 1 battery has required replacement, and 5 other minor faults have been reported. Twenty six (26) have reported that they are satisfied with the system
- Of these users, 26 do understand the basic operation of the system such as; sun being the source of power, charging and discharging of batteries, load management etc.

Figure 6 Enjoying the benefits of DLS

- On an average, these households still use 2 kerosene based devices

The above statistics indicate a very high acceptance as well as demand for DLS, based on the comparison of scenario before and after the installation of DLS.

2.5 Technical evaluation of selected systems

Battery

- 46 households which were selected for technical evaluation, 2 did not have batteries at site. These are currently at Narendrapur, waiting to be replaced by Exide.
- 44 batteries were studied for their daily charging and discharging patterns. Charging current to the battery was measured at 3 different duration of the day. These were 0930-1130, 1130-1330, and, 1330-1600 hrs. Average ampere hrs fed into the batteries during 0930-1600 hrs are presented in table below:

Table 12 Battery charging pattern

Village	Ah received daily	No. of batteries
Katakhali	Less than 10 Ah	5
	10-15 Ah	14
Kumirmari	Less than 10 Ah	3
	10-15 Ah	7
Satjelia	Less than 10 Ah	2
	10-15 Ah	13

- Physical condition with respect to casing, battery terminals and, battery box was found to be good for all the 44 batteries.
- For the purpose of qualitative comparison of battery condition, a grading systems was adopted and batteries were graded accordingly

Table 13 Condition of Batteries

Grade	Battery voltage at no load	SOC (%)	Electrolyte density	No. of batteries
A	12.72 or more	100	1.25 or more	13
B	12.6-12.72	75-100	1.23-1.25	20
C	12.48- 12.6	50-75	1.22-1.23	3
	12.12-12.48	25-50	1.2-1.22	8
E	11.7- 12.12	0-25	Less than 1.2	0

Modules

- Out of 46 modules, 30 were facing true south. 11 were facing southwest, 3 in southeast and 2 were facing east direction. There was more than one reason for these installations. Most of the modules are installed upon thatched roofs, which have sunk over the period and have been deformed. Modules over such roofs have also lost their original directions. In one case, the owner has shifted the module to the east-facing roof that is in the front portion of the house. The original installation, which was on the south-facing roof in the back portion of the house, was not found safe against theft. The owner is aware of the loss of power, but safety of the module is his priority over its utilization. Alternate arrangement such as installation on a pole in front of the house has been discussed with him. In some cases, due to construction, remodeling the house, modules have been reinstalled. South facing direction was nor strictly adhered to in such cases. Shadowing by some nearby structure and by growing trees was also observed.

- Module open circuit voltages were measured to be in the range of 17.5- 19.0 volts
- Module short circuit currents were in the range of :

Time	Irradiation (mW/cm^2)	Short circuit current (amp)
0930-1130	69.32	1.98
1130-1330	86.73	2.42
1330-1600	70.67	1.94

Average ambient temperature at noon was 34.56 ^{0}C

- A comparison of average power output of modules at site with the I-V characteristics of the VLX-53 module provided by the manufacturer at NOCT, showed almost no deviation in the performance of the modules after taking into account additional high ambient temperature.

Other_components

- Average wire lengths in meters from charge controller to module, batteries and load points are given below:

From module	7.17
From battery	2.01
From luminaire 1	3.75
From luminaire 2	5.56
From TV	3.73

- A total of 86 measurements (two luminaires per households) were taken for illuminance directly under the luminaire at an average distance of 1.25 metres between the luminaire and place of work. In 32 cases, lux level was less than 20, while in 54 cases, it was 20- 39. At a distance of 0.3 metres below the luminaire, illuminance was 313 lux, while it was 83 lux at distance below 0.68 metres from the luminaire. As per the Philips manual, 20 lux is the minimum illuminance level required for non-working areas. The scope for improving the illuminance level by altering the angle and height of the luminaire, surroundings, glass cover etc. was not explored.

- In two charge controllers that were non-functional, the terminals for the load connect did not show any voltage
- Average daily Ah consumption calculated on the basis of consumption patterns indicated by the respondents is presented in Table 14 below:

Table 14 Average daily Ah consumption

Village	Consumption of Ah/day (Av.)	Consumption of Ah /day	No. of households
Katakhali	10.06	Less than 10 Ah	7
		10-15 Ah	11
		Above 15Ah	0
Kumirmari	9.68	Less than 10 Ah	6
		10-15 Ah	3
		Above 15Ah	1
Satjelia	10.37	Less than 10 Ah	9
		10-15 Ah	6
		Above 15Ah	0

Figure 7 The DLS in a Goldsmith's shop in village Satjelia

3 Evaluation of SPV systems at village institutions

This chapter presents evaluation of SPV systems that were installed at selected youth clubs that are involved in various community development activities. The objective of providing SPV systems to each of these institutions was different. Basically four type of institution were identified as recipient institutions and systems were given for specific purposes. These were:

Village youth clubs and block coordinating centre

These institutions are involved in a variety of community development activities such as running a library, tuition for children of poor families, drama and social festivals, Mahila Samiti (women organization involved in the gender issues) etc. With the help of SPV systems, these clubs had planned to initiate night schools, extend facility for children to study in its premises in the night, open library in the night, and benefit the group of women in its activities.

Health Centre

The health centre depends on kerosene lamps for most of its activities. It also requires refrigeration facility to store vital drugs such as for snakebite, tetanus. In the absence of refrigerator, the patients requiring these drugs and vaccinations are turned away. Provision for SPV lighting system and a medical refrigerator was made for the health centre to facilitate its routine activities and making it more effective in its service to the community.

Weaving centre and Training-cum-production centre

These centres help local girls and women in acquiring weaving, tailoring and knitting skills, and help them in earning money to make them financially independent. The products from these centres are sold to the local markets or to government organizations. Through SPV lighting system, it was envisaged that these centres would be able to operate additional shifts in the night to increase their productivity and to benefit more members.

Battery charging station

For a typical household in this region, the only source of power for its television set, is the recycled lead acid battery which is regularly charged (once in 30 days depending on its usage) at the DG charging shops. These charging shops are situated in villages which have a market, and villagers from neighbouring areas bring their batteries via cycle rickshaw and boats to these shops. Solar battery charging station has been an innovative concept to provide an environmentally friendly and reliable option for battery charging.

3.1 List of surveyed institutions and their respective systems

Tables below provide details on institutions and systems

Table 15 Institutions and their systems

Name of the institution	Profile of the institution	Installed SPV system (no.)	Date/Month of installation
Katakhali Vivekanand Seva mandir	Youth club	Lighting system design 1 (1)	6th Jan, 1998
Satjelia Vivakanand Milan Sangh	Youth club	Lighting system design 1 (1) Street lights (2)	7th Jan, 1998
Kumirmari Swamiji Sangh	Youth club	Lighting system design 1 (1)	Not yet installed
Chotomollakhali Naba Sakti Club	Youth club	Battery charging station Lighting system design 1 (1) Street lights (1)	Dec, 1998 16th Feb, 1998
Shantigachi Nari Mongal Samity	Weaving and training centre	Lighting system design 1 (1)	18th Feb, 1998
Pakhirala Weaving Centre	Weaving and training centre	Lighting system design 2 (1)	13th Feb, 1998
Satyanarayanpur Health Centre	Health centre	Lighting system design 2 (1) Street lights (2) Refrigeration unit	20th Jan, 1998
Gosaba Rupayan	Youth club (Block coordinating office of RKM)	Battery charging station (1) Water pump (1) Lighting system design 1 (1) Lighting system design 2 (2) Street lights (2)	Nov, 1998

Note. 8 streetlights under this project have been installed by WBREDA at its selected locations

Table 16 Typical design of systems

Type of system (institution)	No. installed	Design details	
Lighting system design 1	6	Modules Battery lights DC outlet Charge controller (Prostar)	2 x 53 Wp 2 x 100 Ah 2 x 11 W 1 1
Lighting system design 2	4	Modules Battery Lights DC outlet Charge controller (Prostar)	5 x 53 Wp 4 x 100 Ah 8 x 11 W 2 1
Battery charging system (Gosaba, Chotomollakhali)	2	Modules System Battery Charge controller (Prostar)	80 x 53 Wp (8 spare) 1 10
Refrigeration system	1	Modules Battery Refrigerator Charge controller (Prostar)	4 x 53 Wp 4 x 100 Ah 1 1
Street Lighting system	15	Modules Battery Lights Charge controller (Tracer)	2 x 53 Wp 1 x 100 Ah 1 1
Water pumping system	1	Modules Inverter Pump unit	16 x 53 Wp 1 1

Table 17 Status of equipment

Component	Total no.	With RKM	With WBREDA	Remarks
Modules	258	239	14	5 stolen (3 from institutions 2 from streetlights)
Charge Controllers	15 (Tracer) 30 (Prostar)	7 30	8	2 Prostar CCs non-functional
Inverter	1	1		
Motor-pump unit	1	1		

3.2 Impact assessment

3.2.1 Katakhali Vivekanand Seva mandir

Type of system- Lighting system

Intended use- to initiate night schools, operate library for members, and, provide opportunity to school children to study in the club premises in the evening

The youth club is situated outside the village Katakhali, surrounded by fields. The building is not fully constructed. It has only one room and the roof is temporary. The club has a piece of land adjoining its building. The caretaker of the club- cum- cultivator of the field resides in the club premises. Due to the incomplete construction of the building, the club has not been able to open a library for its members. The other activities such as drama (Jatra, in local language) practice, study circle etc. take place regularly.

The club has been using the PV lighting system for the past almost two years, without facing any problem. It uses two lights, both installed inside the room, but does not have any DC device to utilize the extra power at the DC outlet. Future plans are there to purchase a TV. Currently, the caretaker is being benefited by the lights for his daily evening chores. In addition, the visiting members from the other clubs who come to stay at Katakhali for drama practice, also find these lights useful for their practice in the night.

However, the most significant impact of the PV system is on the informal school that runs in the club premises at the initiative of the caretaker. In keeping with the focus of RKM to provide benefits to the poorer section of the community, the caretaker provides tuition[1] to about 10 children from 6 to 9 PM every day at a nominal tuition fee. The caretaker, who is busy in the daytime with his club duties, is able to provide tuition in the night because of the facility of the light. The mother of a child who sends her child for tuition to the club said that she would not have been able to send her child to the other tuition centre far away and far more expensive than the club. She felt that the PV light is definitely better than kerosene, and she has felt an improvement in her child's performance at school.

3.2.2 Satjelia Vivakanand Milan Sangh

Type of system- Lighting system. Street light

Intended use- to initiate night schools, operate library for members, and, provide opportunity to schoolchildren to study in the club premises in the evening

The club building is on the outskirts of the village, and is isolated from the village community. The secretary of the club has a radio repair shop in the market, and is also in charge of the payment collection and maintenance for DLS in the village. He has been given basic training at RKM Narendrapur on system installations, repair and maintenance. A street light is installed next to the water tap that is outside the club building. It serves the dual purpose of providing security to the lighting system at the club, and lighting the area where villagers come to collect potable water.

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[1] Tuition is an informal method of teaching where the tutor teaches one or more kids either at his place or at the house of one of the kids. It is in addition to the education which children receive at the formal school. Tuition is seen by the parents as an aid for their children to perform better in their exams

Figure 8 Streetlight and lighting systems in youth club Satjelia

The club has a library, which is operational since 1982, and has 203 members. Number of books being borrowed in a month outweighs the number being read at its premises. The lighting system with both the lights installed in the main room, has not had much impact on the operations of the library because it does not open in the evening hours. The other activities particularly Study circle by the Women community (Chalamana Vahini by Mahila Samiti) has found some use of the lighting system as they are able to shift the time of their meetings to a more convenient 4-6 PM, from an earlier timing of 3-5 PM[2]. As in the Katakhali club, the most significant impact of the lighting system has been the provision for tuition in the club premises in the evening. About 14-15 children receive tuition for two hrs daily, 7 days a week, by two tutors. Prior to the installation of PV system, only 4-5 children used to come to the club for tuition, as hurricane was the source of light. At present there is no load connected on the DC outlet. The system is acquiring popularity among neighbouring clubs and there is an increasing demand. However, the procurement is limited by the funds at the disposal of the club.

[2] As told by the secretary and treasurer of Mahila Samiti

3.2.3 Kumirmari Swamiji Sangh

The club, as stated earlier, does not have a building yet. Plan has been approved for its construction. PV system meant for lighting in the club is currently at Rupayan. The club, however is active in Study circle, Literacy programme, and a Mahila Samiti (Women community) which has 50-60 members at present. The PV system when installed, would facilitate all these activities and would help in initiating new ones such as adult education, cultural and literary gatherings and drama.

3.2.4 Shantigachi Nari Mongal Samity

Type of system- Lighting system

Intended use- to initiate an extra evening shift in weaving and training centres

The weaving and training centre provides training to women in tailoring, knitting and weaving on the handloom. There are currently 10 trainees and 1 trainer per course for tailoring and weaving courses. The centre operates from 11 AM to 4 PM everyday for 6 days a week. Trainees are given a stipend of Rs10 per day during the training period. Payment is made weekly to them. One of the looms in the centre is reserved for the production. The centre produces on an average 3 towels per day, which are sold to the villagers at a rate of Rs 5 per towel.

One of the PV lights is installed at tailoring area on the ground floor; the other is installed in weaving area on the first floor. No load has been connected to the DC outlet. During the festival time the demand increases and extra shift operates between 4- 8 PM. PV light is used for such times. As is the case of most of these clubs and centres, this centre is also situated outside the village. Thefts are therefore a common occurrence in this region. One module and originally installed Exide batteries have been stolen from the centre. It now has one module and two locally made 100 Ah batteries.

The centre has planned new projects for increasing production that would be sold in the local market. Another project is planned for the production of handloom against orders from the government department. With the increase in demand, the night shift will start operating and PV lighting system will be put to its maximum use.

3.2.5 Pakhirala Weaving Centre

Type of system- Lighting system

Intended use- to initiate an extra evening shift in weaving and training centres

The centre had, till 2 modules were stolen in the month of October 1999, a larger PV lighting system with 8 lights. It functioned without any problem till it was disconnected and sent to Rupayan. The centre used to run three shifts in a day: 0800- 1200 hrs, 1400-1700 hrs, and 1700- 2100 hrs, with 4-6 women per shift for production activities. In addition, there are two tutors for training, and 10 students each for weaving and tailoring course. The centre produces items of daily use such as towels, bedsheets, napkins, which are sold in the local markets. It also accepts orders from the Khadi board (central government agency promoting Khadi which is a form of hand woven fabric). Some women after being trained at the centre, become production worker and earn upto Rs 500 per month depending on their output. Centre earns Rs 1500 per month from the tailoring alone. Some of these women travel upto a distance of 2 km to come to this centre.

Since the theft and subsequent removal of the system, the centre has stopped operating night shift, due to which it is loosing approximately Rs 500 per month. Some smaller items like handbags etc. can no longer be made because the other two shifts are busy with executing orders from the Khadi board. At present, there are about 8 women who have lost the opportunity for earning due to no night shift. These women are mainly housewives who used to work in the third shift, as it was the most convenient time for them. The centre reported that these housewives are demanding the reinstallation of PV system. Rupayan has taken a note of it and is planning to reinstall the system soon.

The centre has also made a request for installing a street light in its compound to ensure the safety of the PV system. If the streetlight were installed, one person would also stay at the centre, further ensuring the safety of the PV system.

Figure 9 Women working in dark since the SPV lighting system was stolen in Pakhirala Centre.

3.2.6 Satyanarayanpur Health Centre

Type of system- Lighting system, Refrigeration unit, Streetlight
Intended use- to facilitate the services provided by the health centre due to enhanced lighting, to provide refrigeration facility for keeping essential medicines and vaccines

Health Centre at Satyanarayanpur has 7 rooms, one minor operation theatre, and an adjoining small residential block for the doctor. It has a large PV lighting system with 8 lights and two fans connected to DC outlets. In addition, it also has a refrigeration system for storing essential medicines, vaccines etc. Distribution of the lights is as under:

No. of lights/fan	Location
1/1	Doctor's chamber
1	Medicine room
1	Verandah
2	Operation theatre
1	Patient's ward No. 1
1	Patient's ward No. 2
1/1	Doctor's residence

The health centre also has one street light outside the its building to facilitate the visits of patients in the night, and two solar lanterns given by WBREDA for various other requirements. Most of the cases in the health centre are related to child delivery, snake

Figure 10 Health centre at Satyanarayanpur

bites injuries from iron objects requiring tetanus injections, etc.

The DC refrigerator for the PV system has not yet been supplied by the WBREDA. As a result, the health centre is unable to keep medicines and vaccines required to be kept under refrigeration, such as BCG, tetanus etc. Snakebite cases, which have an occurrence of 4-5 per month in monsoon season, are regularly treated by the quacks and/or experienced elders in the village. However, the cases of fatality are infrequent. For treatment of dog-bites, another common occurrence, victims procure medicine from Calcutta, and transport them in ice packs. Similarly, there is a very large requirement of tetanus medicine, which is injected to every pregnant woman. The requirement is sometimes as high as 10 units per week. In the absence of the refrigerator, these medicines are procured in short supplies and kept in ice procured from local ice dealer.

Prior to the installation of the PV system, hurricane lamps were the only other source of illumination. Delivery cases were usually handled under torchlight, hurricane, petromax or any other device available at the time of requirement. PV lights not only facilitated all such routine activities due to better and reliable illumination; it also helped in special cases of newly born child suffering from jaundice. The doctor followed the practice of focusing 2-3 PV lights on the newly born as a form of treatment to jaundice.

The centre however suffers from a major drawback, as it does not have a committed doctor who is willing to stay in this area for long. Doctors appointed by the R K Mission leave frequently, leaving the health centre in the hands of the compounder (an assistant to the doctor who usually helps in preparing medicines) and nurses. During such periods, the health centre looses its patients and its popularity. At the time of the survey, the centre was running without the doctor since October 1999. A new doctor has been appointed who was yet to join his duty.

3.2.7 Chotomollakhali Naba Sakti Club

Type of system- Battery charging station

Intended use- to provide an alternate and environmentally friendly facility for charging of TV battery

The battery charging station at Chotomollakhali is located inside the village and is accessible easily to those who come from nearby villages to get their batteries charged. The village has one more shop where batteries are charged using DG set. Table below gives an indication of the no. of batteries that come for charging at the club. The number decreases in the monsoon months.

Table18 Number of batteries charged at the centre

Month, 99	No. of batteries	Income (Rs)
April	91	1825
May	96	1831
June	60	1169
July	31	665
Aug	35	703.5

The popularity of the battery charging station is due to its convenient location, publicity of the system done by the club using handbills etc and the competition from only one more charging shop in the market.

The club faces a challenge in terms of skilled technician. The person in charge of the charging station, has not received any training from R K Mission. His is a temporary arrangement till a trained technician is appointed for the club. The members of the club felt very strongly that if the solar charging station has to compete with the DG charging shop which provides a one-stop service for batteries, the former should also provide services beyond the charging such as servicing of the batteries, changing of cells, cleaning of terminals etc.

The solar charging shop faces a bigger threat from a proposed biomass gasifier plant which has been sanctioned by the WBREDA. As experienced in Gosaba, battery charging will slowly shift from solar and DG to gasifier electricity.

3.2.8 Rupayan Gosaba

Type of system- Battery charging station

Intended use- to provide an alternate and environmentally friendly facility for charging of TV battery

The battery charging station at Rupayan, Gosaba is not very popular among customers due to several reasons. A few important ones are as illustrated under:

- There are about 5-6 shops in the market which charge batteries using DG sets. These shops provide additional services such as changing damaged cells in the battery, cleaning terminals, pouring acid, assessing the condition of the battery and informing the user about the same, recycling and constructing new batteries etc.
- Rupayan is located at the distance from the market and from the ferry ghat. Customer is required to spend additional money for transporting the battery to Rupayan.
- Rupayan has not created awareness about the advantages of solar battery charging, and publicity of the centre.

- Customers do not get satisfactory service during rainy season, and are compelled to go back to the DG shop.
- With the supply of gasifier electricity during evening hrs, most households with gasifier electricity connection have installed a small charger at home. They also extend this service to their neighbours.
- There has been no trained technician at the Rupayan to run the charging station. The current caretaker is familiar with connecting and disconnecting the batteries only.

Figure 11 Battery charging station at Rupayan

The centre charges Rs 18 per charge as compared to Rs 22 being charged at the DG shop. A majority of the customers of Rupayan are those who own DLS and come to Rupayan to get their batteries charged during rainy season when their module is unable to charge the battery fully (please note in the table below, the increased no. of customers in the rainy months of August and September). Table below gives an indication of the utilization of the facility:

Table 19 Number of batteries charged at Rupayan

Month, 99	No. of batteries	Income (Rs)
July	14	191
Aug	35	594
Sep	34	574
Oct	16	270
Nov	12	197

Rupayan is planning to introduce some innovative schemes for marketing such as giving incentives to the porter for bringing in customers, and taking 12 fully charged batteries in a rickshaw to the nearby weekly *Haats* for giving temporary light connections to various stalls and shops.

Rupayan also has a water pump, which is installed, in a pond from where water is pumped and stored in a tank about 25-30 ft. high. The stored water is meant for use in

Figure 12. Water pump installed in a pond at Rupayan

training hostel and for vegetable garden. The pond itself meets daily water requirement for Rupayan and pump is not required to run for more than 1-2 hrs. every day. However, when Rupayan is holding a programme and its occupancy is high, pump runs for the whole day.

3.3 Summary of observations

- All the systems have been installed in their respective institutions except in Kumirmari where the building of the youth club is not yet ready. The components for the system are kept at Rupayan.
- All the systems are working except in Pakhirala where 2 modules are stolen. The system has been taken back by Rupayan. Similarly in Shantigachchi, 1 module and both the Exide batteries have been stolen. The system currently works with 1 module and 2 locally made batteries.

- Refrigerator unit at Satyanarayanpur is not installed, as the same has not yet been supplied to RKM by the WBREDA.
- Although the systems are functional, their utilization as intended in the project has been poor. This is owing to the fact that the development of the institutions and the spread of their activities have been slow. For instance, the weaving centre at Shantigachchi does not operate a night shift because there is no demand for an extra shift. Had the centre expanded its activities, PV lighting systems would have facilitated the night shift and an increase in the income of the centre. Similarly, the system at Satyanarayanpur health centre is used only when the doctor is present at the health centre. At the time of the survey, there was no doctor, hence no patients and subsequently, not much use of the PV lighting system.
- The most significant impact of lighting system at the youth club has been on the education of the children belonging to poor families living in the vicinity of the club. These children receive tuition at the club premises in the evening, which has been made possible by the convenience of light. Tuition is given by the graduate youth of the village who utilize this opportunity for an extra (or sometimes, the only source of) income generation.
- Street light in the vicinity of the institution is considered as a good safety measure against theft of PV system installed on it. Since most of these institutions are located outside the village and remain uninhabited in the night, risk of module theft is very high.
- Both the battery charging stations (at Gosaba and Chotomollakhali) face stiff competition with the shops at the market place which offer one-stop service for recycling, refilling, recharging and servicing of the batteries. The electricity source for charging in these shops is diesel generator set. PV battery charging stations offer competitive rates for charging, but they still do not have a steady stream of customers. Although, most of the customers which were interviewed, understood the benefits of slow charging by the PV system on the life of their batteries, it is the other services offered by the DG shops that outweigh all such considerations.

4 Study of other initiatives in the region

This chapter presents the study of similar initiatives in the region other than the NREL ones. Study of these initiatives has provided inputs for preparing a long-term strategy for NREL for planning future interventions in this region.

4.1 Details of initiatives

Table 20 Initiatives other than the NREL

Name of the Initiative	Activities
Biomas gasifier plant at Gosaba	AC electricity supply to households and commercial establishments
Aditya solar shop, Narendrapur	Sale of different SPV systems in Sunderbans under MNES scheme
25 kWp PV power plant at Sagar Islands	AC electricity supply to a village
Padma solar enterprises- private solar shop at Gosaba market	Sale of different SPV systems in Sunderbans under MNES scheme
Comprehensive health project- Tagore society, Rangabelia	Electricity for lights in community health centre
Battery charging shops using diesel generators	Providing charging and other services related to batteries

4.2 Biomass gasifier plant at Gosaba

The biomass gasifier plant at Gosaba was commissioned by WBREDA on 27th January 1997 with an installed capacity of 500 kVA through 5 gasifiers of 100 kVA each. At the time of commissioning, the plant had 25 customers, a number, which has now increased to 450, comprising of both domestic and commercial users. There are no industrial users as of now. Currently, there are 50 more applications, which are pending for getting the connection from the plant.

Out of the five units, only two run at a time because the load is less. Customers applying for the connection are required to pay Rs 250 as security deposit, and another Rs 160 for application fee. An expenditure of Rs 1000 to Rs 1500 is required towards extending the transmission line and some more expenditure for internal wiring etc. WBREDA is planning to supply electricity to entire Gosaba block using the gasifier plant.

The plant is operated and maintained by a staff of 14 people, which includes 2 diploma engineers and 3 linemen. The management of the plant is under the control of a consumer cooperative society.

Domestic users of gasifier electricity pay a tariff of Rs 3.25 per unit, while commercial users pay Rs 3.75. Although there are no industrial consumers at present, the tariff has been fixed at Rs 4.25 per unit for them.

Households, which have both the gasifier and DLS, use the former when it is supplying electricity between 5-11 PM, and use DLS before and after this period for watching TV and for studying in the night. The plant does not operate in the day time as it would require man power for additional operation shift.

Peak evening load on the gasifier is 160 – 185 kW, which reduces to 120-130 kW after 9 PM. Day time load as per the survey done one year back was 60-70 kW only.

4.3 Aditya solar shop, Narendrapur

Rama Krishna Mission Narendrapur, established a solar sales-cum-service centre called “Aditya solar shop” on December 18, 1996 with the support from MNES and WBREDA. From this shop, RKM displays and sells several renewable energy systems under the subsidy based MNES scheme through its network of affiliate organizations. The shop also provides installation and after sales service to its customers. A unique feature of Aditya solar shop at Narendrapur is the existence of a training-cum-repair centre at its premises. The centre is used for providing training to youths from the affiliate organizations that manage the programme at their respective youth clubs.

Aditya solar shop had sold 450 DLS in the year 1996-97, 595 in the year 1997-98 and 589 in the year 1998-99.

The shop and the training centre also provide the technical and man power support required for NREL scheme. While managing NREL scheme, RKM continued to sell systems in the region under MNES scheme as well, which provides a capital subsidy of upto Rs 6000 on DLS. The net cost of the system to the user under MNES scheme is in the range of Rs 7000-1000. Under NREL scheme, it is Rs 7100 with Rs 3500 as down payment and Rs 3600 as loan to be repaid over 5 years. There is no loan provision under MNES scheme.

4.4 25 kWp PV power plant at Sagar Islands

In order to satisfy the growing aspirations of the solar customers, and to serve the population with AC electricity such that they can use easily available end-use appliances, WBREDA and MNES have been promoting the installation of decentralized SPV power plants which supply AC electricity to the village for fixed duration. The concept is popularized as *electrification based planning* instead of *device based planning*, and *provision of electricity* instead of *light alone.*

The region already has six such power plants and some more have been planned for the future. These power plants are used for village electrification as well as for providing electricity to rural hospital.

The plant through a battery bank and inverter supplies AC electricity for a fixed duration every evening. At present, there is no day time supply as there is not sufficient day time load. The billing is on the basis of connected load and not on the actual electricity consumed. The plant with a 25kWp installed capacity, provides electricity to households within 4.5-5 km radius through LT (low-tension) distribution line.

On an average, every plant has 100 consumers who pay Rs 120 per month for 100 watts connected load. Each consumer is expected to pay initial charges for getting the connection and cost for internal wiring etc.

These plants are managed by rural cooperatives, and the revenue collection method is through the account of the co-operative society in the Rural development Bank.

Figure 13 Provision of AC electricity through power plant at Sagar island

Figure 14 25kWp power plant at Sagar islands

4.5 Padma solar enterprises- private solar shop at Gosaba market

Padma solar enterprises is a shop in the Gosaba market place which deals with radio-TV repair, battery charging and related services and sale of DLS as a dealer to Calcutta based manufacturer, who is approved by the WBREDA to sell systems under subsidy.

The shop has a large customer base due to its vast range of business dealing with electricity related appliances. It offers off-the-shelf, as well as custom-built systems, with a variety of options to the customer. Its typical price list looks as under:

Table 21. Typical price list at a private solar shop

System	Price after deducting subsidy[a] (Module type- CEL)	Price after deducting subsidy [a] (Module Type- Tata BP)
35 Wp, 12V- 40 Ah, 2 CFL- 7 Watt each, 1 DC outlet for TV, Charge controller, switch board, 45 ft. wire, complete wiring	Rs 10,000 Rs 1650 extra for fan option	Rs 11,200
40 Wp, 12V- 50 Ah, 2 CFL- 7 Watt each, 1 DC outlet for TV, Charge controller, switch board, 45 ft. wire, complete wiring	Rs 11,325	Rs 12,325
50 Wp, 12V- 60 Ah, 3 CFL- 7 Watt each, 1 DC outlet for TV, Charge controller, switch board, 45 ft. wire, complete wiring	Rs 13,500 Rs 1650 extra for fan option	Rs 14,500
70 Wp, 12V- 80 Ah, 3 CFL- 7 Watt each, 1 DC outlet for TV, Charge controller, switch board, 45 ft. wire, complete wiring	Rs 16,500 Rs 1650 extra for fan option	Not available

[a] Subsidy of upto Rs 6000 per DLS

The shop has been in existence for the past 7-8 years. It sells on an average 10 DLS per month. Upon every sale, the shop offers an incentive of one free replacement of CFL to the customer, and free service for the entire lifetime of the battery. The shop employs 3 technicians. Shop also offers a loan to its customers with a recovery period within one year, and an interest on the bad debt. The shop reports Ten percent bad debts.

4.6 Comprehensive health project and Mahila Samiti-Tagore society, Rangabelia

The Tagore society runs two institutions at Rangabelia, a neighbouring village to Gosaba. These are the Comprehensive health project and Mahila Samiti.

Comprehensive health project

A 5 kWp SPV system was installed at the health project in 1996. It supplies AC electricity through the use of 3 inverters. In addition to the SPV plant, the health project has 2 DG sets (10kVA, 6kVA) which are required to be run for 5-6 hrs. in the morning (5-10.30 AM) for refrigeration of vaccines, and for any emergency requirements at the operation theatre in the night. Otherwise, SPV system provides electricity to 51 lights, 3 fans and 4 street lights.

Solar lights are also used in the morning at operation theatre, Pathology, view box for X-ray plate etc. Streetlights operate from dusk-to-dawn.

The centre reported a very high failure of lamps.

Mahila Samiti

WBREDA has installed 7 DLS in this centre out of NREL project. Contract for installation, maintenance etc. is given to M/s. Exide industries directly by WBREDA.

Figure 15. Women at work under SPV light

The Mahila Samiti runs a Centre for training and production inside its campus. It runs 3 shifts per day with 20 ladies in each shift. The last shift is between 6-10 PM. Sometimes on demand, or during festival season, centre works till late, even whole night. These ladies are residents as well day scholars. Each lady earns on an average Rs 500 – 600 per month.

Prior to installation of the DLS, traditional kerosene lamps were used. Work quantity as well as quality was inferior as compared to present case. Turnover of the centre has increased after the installation of DLS. The centre uses all 14 lights everyday. Till now, no light has been replaced. Minor problems are taken care by local technician. Occasionally, Exide sends its engineers for maintenance, check up etc.

Figure 16. Women at work around kerosene lantern

The residents, as well as the management feel that for a centre such as this, at least 10 more systems are required. At present, 15 kerosene lanterns are used for hand batik work. Women sit around the kerosene lantern and do fine work with hand-brush. Solar lanterns could easily replace these kerosene lanterns.

Diesel generator is the other source of electricity for the centre. Its services are routinely being hired for printing machine, which requires AC supply at the rate of Rs 4 for the usage of 6 hrs. per day. Residents prefer solar systems because they give light for more hours. WBREDA/MNES is planning to extend gasifier connection to Rangabelia. The Hospital as well as Samiti will then have an access to AC electricity.

4.7 Battery charging shops using diesel generators

This evaluation is based on the study of three shops, two at Gosaba Market and one at Chotomollakhali. While Gosaba has 5-6 such shops in the market, Chotomollakhali has only one. One of the shops that was studied at Gosaba, has taken an electricity connection from the biomas gasifier plant and charges batteries using this electricity supply between 5 and 11 PM. Due to the short charging period, batteries are kept in the shop for 4-5 days. The shop charges Rs 20 per charge for 12 V battery, and Rs 6 for 6 V battery. This shop receives 14-15 batteries per week. These batteries mostly come from neighbouring villages via cycle rickshaw (*van* in local language), cycles and boats. A 6 kVA generator is also kept in the shop for additional requirement.

Monthly income for the shop from battery charging business is between Rs 600 to 700 per month. It pays a bill of Rs 450-500 per month for consuming gasifier electricity.

The shop, in addition to charging batteries, does some maintenance and repair on them such as changing damaged cells, filling up distilled water, terminal cleaning etc. Shopkeeper admitted that he had lost some customers to Rupayan initially, but they all came back because they were not satisfied with the service of the Rupayan; charge retention in the battery was one of them[1]. This is contrary to what a regular customer of Rupayan experienced. This customer who has been charging his battery at Rupayan since the system was commissioned, feels that there is no such difference between the two charging. He experienced that his battery life has increased due to solar charging. He pays Rs 18 to Rupayan for every charge. Previously he used to spend a total of Rs 25 (Rs 22 for charging and Rs 3 for transportation), so there is a net saving of Rs 7 for him. The customer is a neighbour to Rupayan.

Figure 17. A typical battery charging stop using diesel generator

The other shop in Gosaba receives about 2-3 batteries every day. The shop has a 10 kVA generator which runs from 10AM to 5 PM as it supplies electricity to the local bank during its working hours. The shop has installed a 72 volt @ 50 Hz , 7-8 amps, charging circuit with series connection for charging batteries. During night time, batteries are charged through gasifier electricity. It takes minimum 20 hrs. for charging batteries and they are usually kept in the shop for 3 days.

The shop charges Rs 16-18 for 12 V 13 plates TV battery. With the typical usage patterns, each battery is required to be charged after 30-35 days. The shopkeeper was candid in admitting that battery charging is no more a profitable business in Gosaba because of two reasons. Although the number of batteries that come for charging to Gosaba every day has increased, number of battery charging shop has also increased accordingly, thereby offering a tough competition. Secondly, individual households have installed battery charging circuits for their own battery, which they charge through gasifier electricity. According to his estimate, there are about 200 batteries in Gosaba alone.

The shop at Chotomollakhali receives 20-30 batteries per week, for which it charges at the rate of Rs 30 for 12 V battery and Rs 10 for 6 V battery. Distilled water cost is extra. The shop has a 4 kVA generator, which operates for 12-14 hrs. Sometime, thirty batteries are put in series at a time for charging.

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[1] Myths such as this need to be corrected by Rupayan if it wants to make the centre popular.

The shopkeeper feels that customers prefer to come to his shop rather than going to the solar charging station because of the complete battery service that he gives, in addition to recycling the batteries for them.

To summarize, the local battery charging shops score over the solar charging stations on the consumer satisfaction because the former give them complete service and advice, which they do not receive from the solar charging stations.

Figure 18. Mahila Samiti shop doing business under solar lighting

5 Long term strategy

Evaluation and impact assessment of SPV systems on the users and on the community at large, has ascertained the continuing need for electricity through the use of SPV systems in this region. Simultaneously, case studies of other interventions have provided an insight into the existing situation with respect to electricity requirements and supply options. The chapter draws a long-term strategy for NREL to plan its activities in this region based on the inputs from the above two exercises. The aim of the planning is such that the synergy of the existing and proposed interventions helps in the overall development of the region.

5.1 Improved utilisation of available hardware

As stated in the report, there are 290 DLS, 10 institutional lighting system, 1 water pumping systems, 7 street lights, and 2 battery charging stations that are installed by RKM in this project. Majority of the systems is functional and has not faced any major technical problem during their operation. While the usage of DLS has been high, the utilization of institutional systems for their intended end-use has been rather poor. Based on the evaluation of DLS, beneficiary institutions and other similar initiatives in the region, following specific interventions are proposed with an aim to provide inputs to NREL for a long-term strategy.

5.1.1 Utilization of DLS

Using the manufacturer specified data on typical electrical characteristics of module, a preliminary calculation shows that the system can be made more useful within the existing capacity, if the load management is introduced in coordination with the owner of the system.

Typical Electrical Characteristics of Module

Model	VLX 53
Typical Peak Power (Pp)	53 W
Voltage @ Peak power (Vpp)	17.2 V
Current @ Peak power (Ipp)	3.08 A
Short circuit current (Isc)	3.33 A
Open circuit voltage (Voc)	21.3 V
Temperature coefficient of Voc	-73mV/ ^{o}C
Temperature coefficient of Isc	2.5mA/ ^{o}C

1. At the measured ambient temperature of 35^{o}C, and at 87mW/cm^2 irradiation, the cell temperature is estimated to be around 61^{o}C using the equation[1]
2. Applying the temperature coefficient to the current, the corrected Ipp would be 3.23 A
3. Assuming 5.4 Equivalent Hrs. of Full Sunshine (EHFS) at site, the Ah gained from the module on a typical day would be 17.4
4. Considering an 85% nominal energy efficiency of the battery, the total Ah available for use from the battery would be 14.8
5. In a typical day, 14.8 Ah is used as, - 7.2 Ah between two 9 W lamps, and 4.6 Ah by the B/W TV[2]. Remaining 3 Ah can easily be utilized for some extra load
6. Instead of two lamps, four lamps can also be used for 2 hrs. each, or any other combination found useful by the user

The system with the available module and battery capacities can be made more useful if the load management as explained above can be introduced in consultation with the owner of the system.

Enabling activities and other inputs required to implement the above:

- Awareness campaign by RK Mission with demonstration of load management results to a few users
- Supply and installation of new luminaire for those who are willing to buy at cost
- Setting up of a shop-cum-repair centre at Rupayan

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[1] Green, M.A. (1982) in his book "Solar Cells: Operating Principles, Technology and System Applications" states that *as a rule of thumb, most commercial modules allow the cell temperature to rise about 30^{o}C above ambient temperature under full sun irradiation when mounted on an open frame. Hence the approximate expression for cell temperature is Tcell=Tamb+0.3xIntensity(mW/cm^2)*

[2] Calculations are based on actual usage as measured in 46 households where detailed system performance was evaluated

5.1.2 Utilization of water pumping system

The water pump is currently installed at the small pond in the premises of Rupayan. The pump is intended to be used for lifting and storing water in the overhead tank which stores water for use in the hostel building. Some quantity of water is also used for irrigating a small vegetable garden.

As a back-up to the SPV pump for lifting water to the storage tank (at about 25-30 feet height), a hand pump is installed which is also used routinely. It was noted that at the time of evaluation, the SPV pump was not operational and the hand pump was extensively used. As per Rupayan sources, the system was installed by M/s Exide through another sub-contractor, and was still under warranty period. A visit by the technician was awaited.

The pump is found to be useful when Rupayan holds training programmes, meetings etc. and the occupancy in the hostel is high. However, on any other normal day, the demand for pumped water is low, and the pump is switched off. In Sunderbans, every dwelling has a small pond attached to it. Majority of daily chores are done by the side of the pond and the practice of storing water is followed only for drinking purposes. In view of this practice, the SPV pump is utilized occasionally. Further, due to the availability of hand pump at Rupayan, SPV pump is often used only as a back-up system when large quantities of water is required.

For the better utilization of the pump, Rupayan has to ensure its trouble free operation which has not been the case in the past. As no. of programmes and other activities increase in Rupayan, pump will be put to its maximum use.

Reinstallation at an alternate site is not recommended because the pump can be best utilized at a community centre where there are a large number of people living at a time. Rupayan being the block office, offers this potential.

5.1.3 Provision of lighting systems to more youth clubs in a cluster

The project has benefited individual households in the region by way of making DLS available at affordable prices. It has benefited the community at large by strengthening community centres, which are involved in its overall development. Through these community centre systems, benefits of SPV have reached those who do not have an access to individual DLS.

Evaluation indicates that the SPV systems have not been much helpful in initiating any new activities at the centres, and hence, have not had a measurable impact on the community. Nevertheless, they have facilitated the activities and functions of these centres, making them more popular and effective. This facilitation by itself has created a demand for similar systems in nearby centres, which are constrained by funds to buy systems on their own. In this context it is to be appreciated that development work by its very nature is slow. These centres which have had SPV systems for over two years, have experienced benefits which may not be quantifiable as yet, but are noticeable enough. For example, the evaluation of Satyanarayanpur health centre indicates that the SPV system has been used to its fullest when the centre has a resident doctor. Similarly, the system at Pakhirala weaving centre was benefiting the individuals who work there till it was removed after the theft of the module.

In view of the above considerations, it is proposed that while NREL and MNES can monitor the progress of these institutions at regular intervals, the community developmental work, which the Project initiated, should not be stopped. On a similar pattern, sizeable number of (at least ten) lighting systems can be provided to more community centres, which are involved in various developmental activities in the region.

Enabling activities and other inputs required to implement the above are:

- Funds for financing at least ten lighting systems for Youth Clubs
- Funds to be sanctioned under the condition that within a period of one year, Rupayan coordinates the development of recipient Youth Clubs such that they are able to utilize their existing SPV systems
- Stringent criteria with quantifiable monitoring indicators to be developed (using tools such as Log Frame Matrix) in association with RK Mission to evaluate the overall progress of the Clubs' activity and utilization of SPV systems
- New clubs to be selected in a cluster to maximize the impact on the community in a particular region
- Time bound commitments for financial and institutional support, and an implementable plan to be made by the selected clubs, for utilization of SPV systems
- Redesign of proposed systems with indigenous components to the extent possible
- Provision of at least one street light in the vicinity of the club for security of the lighting system

The above would formulate the scope for Business Plan 1 for providing lighting systems to more Youth Clubs and through them, expanding benefits of SPV systems to the community

5.1.4 Rehabilitation of battery charging stations

Battery charging station at Rupayan, as evaluated in the current study, is unable to achieve its set goals and has not found acceptance among community for a multiple of reasons already discussed in this report. In terms of hardware, it has 80 modules, 10 Prostar-30 charge controllers, and other accessories, which are in good condition. Although, Rupayan has indicated plans for improving the popularity of the charging station, a more pragmatic approach in view of the growing competition with biomas gasifier plant, would be to dismantle the station and rehabilitate the hardware.

The evaluation has indicated a high demand for more DLS in the area under the Indo-US scheme. Modules, all 80 of them can be utilized for providing DLS to 80 more users. Rest of the components, such as the battery, charge controller and luminaire can be procured locally. New users can be provided with a loan scheme from the revolving funds created in the project. Prostar-30 charge controllers can be utilized for additional ten youth club lighting systems that is proposed in the section 5.1.3.

Section 5.2 discusses a financial plan for rehabilitation of hardware using revolving funds.

Battery charging station at Chotomollakhali is better utilized as compared to that at Rupayan. However, WBREDA has sanctioned a biomas gasifier plant for Chotomollakhali for which feasibility study has been completed. Allowing a time span of two years for; a) executing the rehabilitation plan for Rupayan and monitoring its success/failure, and b) for biomas gasifier plant to be commissioned at Chotomollakhali, year 2002 would be an appropriate time to study the feasibility of rehabilitating the charging station. Next two years would also give sufficient time for Chotomollakhali youth club to prove the success or otherwise of battery charging station.

Enabling activities and other inputs required to implement the above are:

- Approval from NREL and MNES to go ahead with dismantling and rehabilitation
- Man power commitment from RKM to undertake dismantling
- Identification of new customers and marketing of proposed scheme
- Funds from revolving fund
- Reliable source of remaining hardware
- Monitoring to see that the modules are utilized for DLS and not for any other application
- Mandate for Chotomollakhali youth club to popularize the battery charging station after looking into its requirements such as provision of minimum tools and instruments, skilled technician to provide complete battery servicing, etc.

Rehabilitation of Rupayan battery charging station can be executed through a formulation of Business Plan. (Business Plan II)

5.2 Utilization of existing funds for future expansion of the DLS programme

As per the original scheme, the project has generated revolving funds, which are meant for providing loan to customers for replacing their batteries in future. Following sections propose a plan of action for utilization of these funds such that a part of the total funds collected are used for expansion of the project aimed at benefiting individual users

5.2.1 Current financing scheme and status of funds

As per the original scheme of financing, users are paying an installment of Rs 60 per month. The utilization of Rs 60 is shown in the box: *(details in sheet 1)*

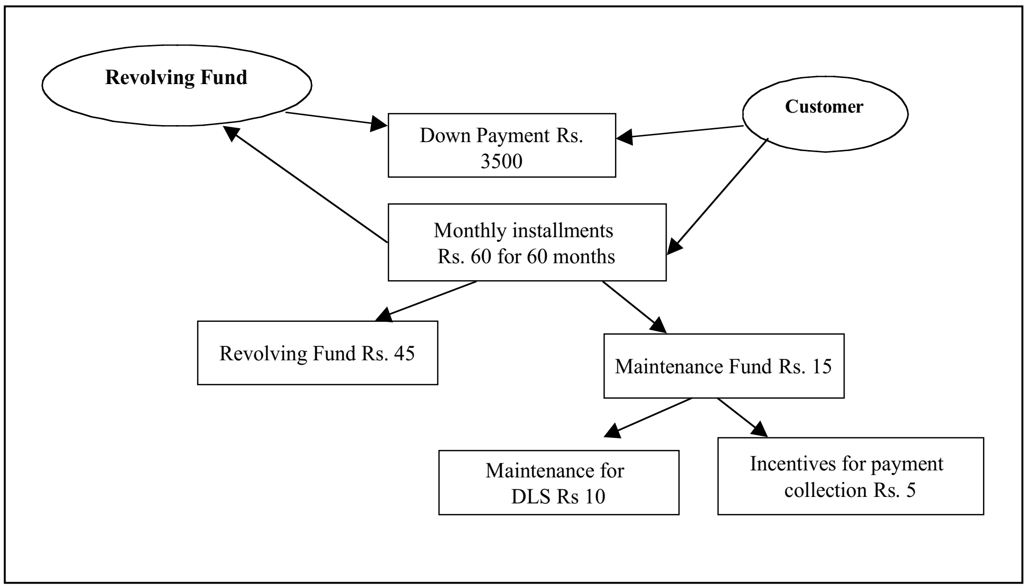

Figure 19. Current financing scheme

Sheet1 **FINANCIAL STATUS AS ON 24/9/99**

Project cost summary

		Expenditure	Income
Fund received from MNES- ***A***			**7500000.80**
Customs and clearing- ***B***	4670960.00		
Payment to Exide against work order Rs.3120421.00- ***C***	2620808.00		
Expenditure incurred as on date D=(B+C)		**7291768.00**	
Balance fund at hand E=(A-D)	208232.80		
Retention 10% payment to Exide- ***F***	262080.80		
Total at hand G=(E+F)	470313.60		
Funds to be received from WBREDA- ***H***			**291381.00**
Expenditure to be incurred on Exide (3120421-C)- ***I***		**499613.00**	
		7791381.00	**7791381.80**

Payment collection summary

Village-systems	Due	Recovery	Balance	Revolving	Maintain	spent on maint.	Balance maint.
Katakhali -90	145800.00	141550.00	4250.00	106162.50	35387.50	11795.8	23591.70
Satjelia-100	156000.00	148500.00	7500.00	111375.00	37125.00	12375	24750.00
Kumirmari-100	150000.00	121320.00	28680.00	90990.00	30330.00	10110	20220.00
Total-290	**451800.00**	**411370.00**	**40430.00**	**308527.50**	**102842.50**	**34280.80**	**68561.70**

Revolving fund summary

Down payment collected on 290 systems @ Rs. 3500.00		**1015000.0**
Monthly installment @ Rs. 60	17400.00	
Revolving fund component Rs. 45	13050.00	
Maintenance component @ Rs. 15	4350.00	
Total installment collection due in 60 months		**1044000.0**
Total collection due for revolving fund	783000.00	
Total collection due for maintenance fund	261000.00	
Total recovery due from the customers		**2059000.0**

Revolving Fund

- The project has two sources of revolving fund; from the initial payment of Rs 3 500 per system (component A), and from three-quarter of the monthly installment of Rs 60 per system (component B).
- According to Rama Krishna Mission sources[3], the total amount collected from component A is Rs 10 15 000.00, and from component B (290 systems, an average of 28 installments (or month) per system), is Rs 3 08 527.50 till date. Total revolving fund collected is Rs 13 23 527.5
- Out of this amount, Rs 58 000.00 has been utilized for various expenses including project management. This amount equals to an average of Rs 7.14 per system per month.
- Balance Revolving funds at hand are Rs 12 65 527.50, out of which Rs 10 00 000.00 are kept with Rama Krishna Mission, Narendrapur, while remaining Rs 2 65 527.50 are with Rupayan.

Maintenance Fund

- Out of the monthly collection of Rs 60 per system, Rs 15 go towards maintenance funds. Total amount collected towards maintenance fund from 290 systems for an average of 28 months, is Rs 1 02842.50.
- A total of Rs 81 007.68 has been utilized towards maintenance of these systems so far. It amounts to Rs 9.98 per system per month calculated from an average of 28 installments per systems for all 290 systems.
- Balance Maintenance funds of Rs 21 834.82, are kept with Rupayan.

On an average, Rs 17.12 have been spent per month on every system towards payment collection incentives, maintenance and other overheads, as against Rs 15 stipulated earlier.

(Details in Sheet 2)

5.2.2 Proposed generation and utilization of Revolving funds

Generating Revolving funds

As on date, a total of Rs 12 65 527.50 is collected towards revolving funds, and Rs 21 834.82 towards maintenance funds. R. K. Mission, Narendrapur suggests that the

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[3] The source of above information is not an audited statement of account from Rupayan Office. It is from a summary statement prepared and kept in records by Rupayan for internal purpose.

Sheet 2

Fund Generation	Due	Received	Balance due	Utilized	Balance at hand
Revolving fund					
Down Payment	1015000.00	1015000.00	0.00	0.00	1015000.00
Installments	783000.00	308527.50	474472.50	58000.00	250527.50
Total Revolving	1798000.00	1323527.50	474472.50	58000.00	1265527.50
Maintenance fund	261000.00	102842.50	158157.50	81007.68	21834.82
Total	**2059000.00**	**1426370.00**	**632630.00**	**139007.68**	**1287362.32**

Revolving fund utilization	
Down payment	1015000.00
Installment	308527.50
Total collection	**1323527.50**
Amount kept with Rupayan	265527.50
Amount kept with LSP, Narendrapur	1058000.00
Amount utilized by LSP on project manage	***58000***
Balance left with LSP	1000000.00
Funds at hand	**1265527.50**

Maintenance fund utilization	
Funds collected	**102842.50**
Funds utilized on DLS	34280.80
Funds utilized by Rupayan	46726.88
Total utilization of funds	***81007.68***
Funds left with Rupayan	**21834.82**

entire Revolving funds generated so far may be kept at Narendrapur for future utilization, which has not yet been planned.

In addition to the collected amount, Rs 4 74 472.50 is yet to be collected towards revolving fund, and Rs 1 58 157.50 towards maintenance funds, provided the collection is 100% for the project.

Past experience indicates that the total amount spent so far on maintenance and other management related expenses are Rs 17.12 per system per month. Hence, there would be a total requirement of Rs 1 57 760 over the next 32 months to maintain all systems, which can be met by Rs 1 58 157.50 yet to be collected.

In another scenario, a more realistic approach could be considered where Rs 20 is allocated per system per month for maintenance. Rs 10 would go towards actual maintenance and Rs 10 would be for incentives for payment collection as against the current practice of Rs 5. With a total income of approximately Rs 1,000 per month, the person in-charge for payment collection and routine maintenance would find the job more lucrative, and perhaps worth dedicating his efforts into.

The total amount required to be collected towards maintenance and payment incentives, for all these systems for next 32 months, would now be Rs 1 85 600.00. To manage the required cash flow, instead of the current practice of keeping Rs 45, Rs 40 can now be deposited with the revolving fund. Remaining Rs 20 could go towards maintenance funds.

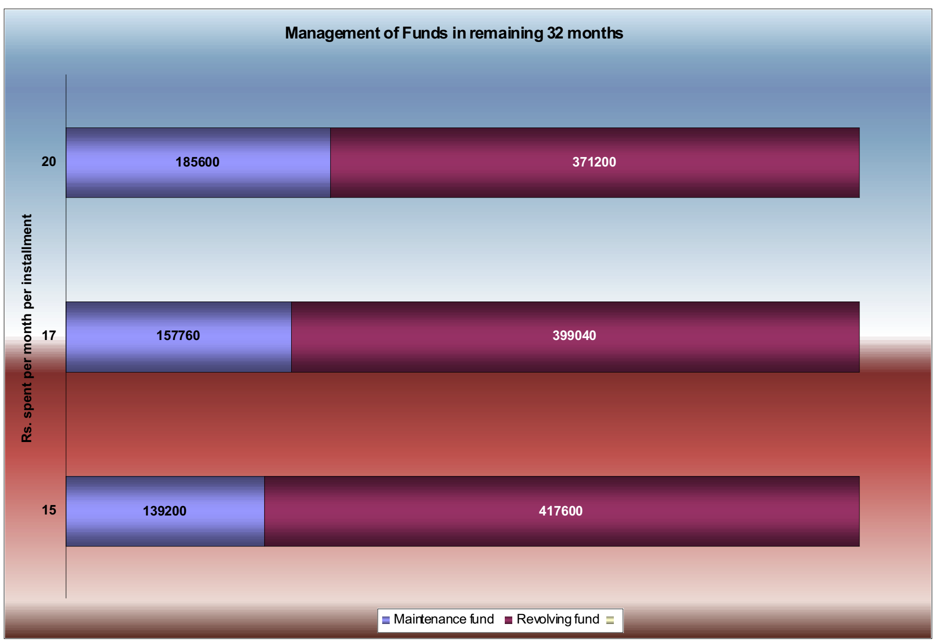

Figure 20. Management of funds in remaining 32 months

If the above suggested scenario were followed, a total of Rs 3 71 200.00 would be contributed towards revolving fund in the remaining period of the project. Adding to it a sum of Rs 12 65 527.50, which is the *balance at hand* from the total collection till date, the project would have contributed a sum of Rs 16 36 727.50 towards revolving fund. On the other hand, the maintenance funds generated would have been completely utilized.

Utilising Revolving funds

The amount of Rs 16 36 727.50 distributed equally among all 290 customers would enable them to take a loan of Rs 5 643.88 each to replace the battery at the same time. All customers can thus access the revolving fund at the same time to take loan, if required.

Alternately, if only 82.5% of the total funds are revolved at a time for providing loan to existing customers, remaining 17.5% of the funds or Rs 2 86 427.22 can be revolved for providing loan to new customers who want to procure balance-of-systems for the modules from the dismantled battery charging station.

Given below in the box, are basic calculation which show how 80 modules dismantled and recovered in good condition from Rupayan battery charging station can be utilized to provide systems to 80 new customers with the same financing scheme as the current one. (Phase II)

Assumptions

- If all the modules from the Rupayan battery-charging station are recovered in good physical and operating condition, then 80 new customers can be provided with DLS in Phase II.
- Cost of the system with 53 Wp module, 75 AH battery, and two lights with one DC outlet is estimated to be Rs 14 500 according to the prevailing prices in the region of similar designs of DLS.
- The module costs Rs 7 500 and BOS cost is Rs7,000.
- The module is given free of cost to the customers, the rest of the system including installation charges are financed by him.
- Of the total Rs 7 000 that a customer is required to pay, Rs 3 420 is self-financed (*compare it with Rs 3 500 down payment in original scheme-Phase I*), and Rs 3 580 is given to him as loan by RKM which he is required to pay back in 60 months at the rate of Rs 60 per month (*similar to the payback scheme offered originally*).
- For financing Rs 3 580 each to 80 customers, an amount of Rs 2 86 400 is required, which is equal to 17.5% of the total revolving funds (*Rs 16 36 727.50*) that would be generated in the project..
- Eighty new customers in Phase II can easily be financed from the17.5% of the revolving funds created in Phase I of the project.

If proven successful, the battery charging station at Chottomolkhali can also be dismantled 28-30 months after the beginning of Phase II. 80 new customers (Phase III) can be financed in a manner similar to Phase II with Revolving funds generated in Phase II till that period, and some additional borrowing from Revolving funds in Phase I. (Table 1 below)

Table 22 Financing new customers from Rupayan battery charging station

Revolving funds available (17.5% of Rs 1636727)	**286,427**
Cost of system	14,500
Module cost	7,500
BOS cost	7,000
Modules from Rupayan	80
Module cost to customer	0
Initial expenditure by the customer	3,420
Loan from Rupayan	3,580
Total loan requirement for 80 customers	**286400**
Down payment to Rupayan	0
Monthly instalment	60
Total no, of instalments	60
Total instalment collection from 80 customers	288,000
Maintenance expenditure @ Rs 20 per month per system	96,000
Revolving fund generated	192,000

5.3 Capacity building and institutional development

5.3.1 Setting up of shop-cum-repair centre at Rupayan

While studying the other initiatives for DLS market in the region, an important observation was the success of one-stop-shop concept. Usually the local dealer of the SPV manufacturer provides hardware, options for system design, installation, credit and after sales service. For all the interventions that are proposed above (improved utilization of DLS, provision of ten more lighting systems for youth club, new customers through rehabilitation of battery charging station), it is important that Rupayan acquires the skills, infrastructure and profile of a one-stop-shop for SPV systems.

In the current project, role of Rupayan was more of a facilitator between the customer and the component supplier and/or RKM Narendrapur. For example, if a customer had a complaint regarding mal-functioning of the luminaire, Rupayan depended upon Narendrapur for fault repair or to the component supplier for replacement of the component.

For expansion of SPV market and for the success of other proposed interventions, it is important for Rupayan to establish a Solar Shop-cum-repair-centre with following facilities.

- Inventory of stocks for modules and batteries
- Tools and necessary instrumentation
- Skills for assembly and repair of luminaires and charge controllers

- Skills for system design options and installation related services
- Skills for management of credit

Specific training requirements to facilitate the above, are discussed in the next section

5.3.1 Enhanced training on component repair and system assembly

In the current project, training was provided to select professionals from RKM on maintenance aspects such as on-line fault repair, battery maintenance, replacement of components etc. Trained technicians now feel the need to enhance their skills in repairing and servicing of components such as charge controllers, inverters etc. As the systems are in use for more than two years now, and have completed their warranty period, technicians realize the practicality of repair of electronic components, rather than their complete replacement. As of now, the entire luminaire assembly has to be sent back to the supplier if it mal-functions. If RKM technicians were skilled in repairing these components locally, the customer would have to pay less for maintenance as compared to complete replacement. However, it has to be borne in mind that such a training would be fruitful only if charge controllers, inverters etc. are procured locally for these interventions. Components imported from USA would be unrepairable in the field.

In addition to the above, training programmes on concepts of system design and optimization, component selection, procurement procedures, contract development particularly with vendors, and management information system would add to the holistic development and self-sufficiency of the centre.

5.3.2 Skill acknowledgement and scope for professional development

One of the crucial problems faced by RKM in general and specific to this project is its high turnover of skilled staff. It was indicated to the evaluation team that the current job profile of these skilled technicians does not provide them with any challenges. Maintenance of systems is a mundane job with no future scope of professional development. It has been observed that skilled technicians who stay back in these villages and continue to work are those who are natives of that village and have their families and belongings in that village. While it is recommended that this fact be given prime importance in selecting technicians for a particular region, a more attractive professional development plan has to be worked out to retain them in future.

A training in design, assembly and complete servicing of systems would not only add to the self-esteem of the technician, it will also give him an option of working on turn-key contract with RKM rather than being on fixed salary. Another activity to make the job more attractive for technicians would be to involve them in training-the-trainer programmes for other organization both within and outside the country. After receiving a complete training on all the aspects discussed above, RK Mission and/or its individual members can be identified as trainers to initiate similar projects elsewhere.

A detailed business plan (Business Plan III) could be formulated for specifying the duration, scope, candidates, faculty, etc. for capacity building programmes.

5.4 Prospects for new initiatives

New initiatives proposed here are based on the assessment of electricity requirement at the domestic level, as well as at commercial level. While the evaluation indicated a high demand for SPV electricity at domestic level for commercial purpose, it is for small shops that the SPV systems are most needed. Each village has a number of small shops which are primarily for tailoring, cycle repair, radio/TV repair, grocery etc. These shops use either a kerosene lantern or a petromax in the evening for doing business. In bigger markets, AC electricity is provided by DG set on a per-bulb basis.

Other business activities, which require power, are timber cutting and floor mill. Provision of SPV electricity to such businesses was not explored.

For the supply of SPV electricity for domestic purposes, two options are currently in use; DLS (DC electricity) and power plants (AC electricity). DLS has already proven to be a viable market, which is being serviced by a few manufacturers utilizing MNES subsidy scheme. Power plant, on the other hand, is a relatively new concept, which is currently being promoted through the joint efforts of central and state governments.

Although there is still a sizeable population in the region which can not afford DLS even after the subsidy, parallel schemes (NREL and MNES) for the same product with different financing options, may not prove healthy for the development of the market. In addition, DLS is limited in making provisions for additional power for either domestic or commercial purpose.

In view of the above, a new initiative by NREL in the form of setting up a 25 kWp power plant for supply of AC is proposed, which will support and complement the efforts of local government to popularize the concept which has potential for commercial viability in future.

5.4.1 Setting up of 25 kWp decentralised power plant for supply of AC electricity

Rationale

The recommendation to set up decentralised power plant for supply of AC is based on the increasing popularity of the approach of WBREDA and MNES for providing grid quality electricity to the local population using decentralised power plants. Although the demand for DLS exists in the region, the provision of electricity through biomas gasifier has attracted the customers towards a solar system that provides AC electricity. Since it is practically impossible to link this region with high voltage transmission grid of the state utility due to almost insurmountable technical problems and high cost of the system involved, the only other alternative for AC power in the region is through individual diesel generating sets which sell power on a single bulb point basis for fixed hours daily. There is no provision for supply of 220 volts AC to run TV sets and other appliances. Through the installation of decentralised power plants with small length of LT distribution line, WBREDA and MNES have been able to provide grid quality electricity to selected communities in the region. Six power plants of 25-26 kWp capacity have already been installed in different villages. Out of these, one has been dedicated to a hospital.

Although it is less expensive to service same number of customers through DLS than through power plant, the advantage of latter over former is the quality and quantity of power.

The rationale for proposed initiative is to expand the already popular programme which otherwise would be limited by the funds from local resources.

System specifications

A typical 26 kWp plant uses either 50 or 75 Wp crystalline silicon modules. With a battery bank capacity of 1600 Ah, and inverter capacity of 45 kVA (3x 15 kVA each), input at 120 VDC, the plant provides 3 phase 400 V 50 Hz AC within 6 km of the LT line. One of the plants, which have been commissioned recently (April, 1999), services 85 consumers with a target to service a total of 120 consumers. Total land area taken up by the plant is about 550 sq. m. [4]

Financing and operational details

These plants are currently being financed partly through subsidy and partly through loan from IREDA under World Bank line of credit. For a typical installed cost of Rs 80 lacs, (without including the land cost) grant component from central and state is about Rs 50 lacs. Remaining Rs 30 lacs comes as a loan from IREDA at one percent interest with a repayment schedule of 10 years[5].

The operation of the plant is through a cooperative, which looks after the O&M, payment collection and several other aspects such as salary to the caretaker. Each consumer is required to deposit an initial sum of Rs 1000 towards getting the connection

[4] Published and printed material from WBREDA for public circulation
[5] Additional region specific concessions

with fixed connected load. He has to bear the cost of internal wiring, and a payment of Rs 120 per month with 5% increase in every three years, for using power at 5 points for 5-6 hrs. every evening. Monthly tariff has been fixed based on the load controller rating instead of installing energy meters. [6]

Socio-economic and environmental benefits

The power plant provides real and measurable socio-ecomic benefits as it replaces the diesel generator set which is the only other source of the electricity supply in that region.

The power plant is expected to generate 35,000 kWh units of energy per annum. Assuming diesel generators produce about 2.85 kWh per litre of diesel fuel, its replacement by solar power plant translates to a diesel consumption reduction of approximately 12,280 litres per year. Based on carbon dioxide emission rates of 2.71 kg per litre of diesel fuel, this equates to an approximate reduction in carbon dioxide emission of 33.3 metric tonnes per year.

In terms of social benefits, the provision of electricity has helped the population in utilizing their evenings in more productive activities such as education, business, trade and agricultural production. It has brought the population closure to the national and international events through the TV and radio. Most significantly, it is the environmentally friendly alternative for supplying electricity to the people of the region.

5.4.2 Solar lantern charging –cum-renting shops

Rationale

As a part of the case study of other initiatives in the region, a niche market appeared of provisions of lights for shops in weekly *Haats* (bazar). Particularly in Chotomollakhali and Sajelia, a strong demand came from the villagers for solar based lights for their weekly haat. Villagers in Chotomollakhli are relatively poor as compared to those in Gosaba. Very few of them can afford a DLS under any of the existing schemes. On the weekly haat day, shopkeepers from this village as well as those who come from neighbouring villages set up their shops in the open area. The source of lighting in these shops is either Petromax or the single bulb (60-100 Watts) connection from the diesel generator operator who charges upto Rs 5 for giving electricity for 3-4 hrs. Although the expenditure of Rs 5 is affordable to most of these shopkeepers, it is unreliable service that bothers most of them. If the generator is unoperational on the day of the haat, shopkeepers are left with no option but to do their business with the help of kerosene

[6] Gonchodhury S P. 1999. *Development of Solar Photovoltaic Power in West Bengal* in International Workshop on Eco Friendly Electrification in Off Grid Areas with Quality Power

lamps. On a haat day, there are more than 100 customers who take temporary power connection from the DG set.

Technically, Solar lantern is an ideal option to DG powered single bulb, petromax or kerosene lamp in above scenario. Financially, renting them on daily basis is a viable option as very few shopkeepers are able to afford the product at its current price. Similar initiatives have been tried in the region.

System specifications

System specifications are based on an available model in the country which uses single module for charging 10 lanterns simultaneously. As a part of the system, a 40 Wp module along with a distributor, multimeter and cables for 10 lanterns is installed at the place of the service provider. Upto 10 lanterns can be connected and charged at the same time using charging plugs. In the evenings, they are disconnected to be ten mobile lanterns at the disposal of the user. These lanterns can store 3-5 light hours per day. [7]

The above model has been used only for a reference in this study. For implementation, a scan of available models would be the basis for selection.

Financing and operational details

The total cost of the system is Rs 39 000 which includes 10 lanterns, and a charging station inclusive of distribution box, multimeter and solar module.

Users pay the charging fee, which has to be decided based on the current expenditure on alternative. (Rs 7 per day on Petromax, Rs 5 per day for DG electricity). The operator of the system keeps a part of the collection for operating and maintaining the system. The rest of the collection goes to the provider of the facility, who in this case would be RKM.

Each village can have five such stations, all being managed by a single operator. If Rs 4.5 is collected per lantern per day, each village will generate Rs 225 per day. This collection may be equally divided between i) a revolving fund for replacing the batteries and other maintenance requirement, ii) income to the club, and iii) an incentive/ salary to the operator. Assuming the collection per month per village is Rs 3 375[8], each village will generate an amount of Rs 40 500 per year which would be equally distributed among the three cost heads. (Rs 13 500 per annum each towards revolving fund, income to the club, incentive to the operator)

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[7] Auroville Energy Products, Auroville

[8] All the lanterns may not be used every day. Current scenario assumes that each lantern is charged and rented 15 times a month for various functions such as haats, social ceremonies, daily usage in the households etc.

Socio-economic and environmental benefits

If ten villages are identified as beneficiaries for this initiative, and 5 systems are provided per village, it would directly benefit 500 users per day for an average 15 days in a month. In one year, it would have benefited 90000 users who otherwise would be using DG generated electricity on a per bulb basis.

If these 90000 users accept solar lanterns in place of a 60 watt bulb for 3 hrs. from the DG electricity, it would amount to a saving of 16,200 kWh of DG electricity per annum.

Following the above calculations, (diesel generators produce 2.85 kWh per litre of diesel fuel, carbon dioxide emission rates of 2.71 kg per litre of diesel fuel), replacement of the DG set by solar lanterns would reduce 15.4 metric tonne of carbon dioxide per year.

Other than the quantifiable benefits, the most significant benefit to the community would be the reliable and assured service at the time of their requirement. The haat would also be free from temporarily set up electricity distribution system using loose wires and poles. In additions, villages will have an access to the lantern as and when they require.

For both the above interventions, a comprehensive Business Plan may be made which will provide a road map for their implementation. (Business Plan IV)

5.5 Summary of recommendations for long term strategy and required inputs

5.5.1 Proposed set of intervention, and their cost assessment

Table 23 Proposed set of intervention, and their cost assessment

Proposed intervention	Details of activities	Preliminary costing	Strategy for implementation
Improved utilization of DLS	Additional luminaire through local suppliers	Self financing by customers	Awareness creation by Rupayan
Utilization of Water pump	None	None	
Provision of lighting systems to more Youth Clubs Requirement of 20 street lights (2 per club)	▪ Supply of modules from USA, preferably thin film based ▪ Charge controllers from dismantled battery charging station ▪ Battery and Luminaire from local suppliers	Rs 3 00 000 (an average of 100 Wp system) Rs 7 00 000	Formulation of Business Plan as per the scope in section 5.1.3
Rehabilitation of Battery charging stations	▪ Dismantling the station ▪ Finding new customers ▪ Provision of supply of battery and other components through solar shop-cum-repair centre at Rupayan	Rs2 86 400 (to be financed from the revolving fund)	Formulation of Business Plan as per the scope in section 5.1.4
Capacity building and institutional development	▪ Setting up of shop-cum-repair centre at Rupayan ▪ Enhanced training on component repair and system assembly ▪ Skill acknowledgement and scope for professional development	To be assessed through detailed planning	Formulation of Business Plan as per the scope in section 5.4
Setting up of 25kWp decentralised power plant for supply of AC electricity		Rs 80 00 000	Formulation of Business Plan as per the scope in section 5.4
Solar lantern charging –cum-renting shops	Setting up 50 charging stations distributed in 10 villages	Rs 19 50 000	

Total amount required for proposed interventions based on preliminary costing is Rs 1 09 50 000 or US$ 248 864 (Rs to US $ conversion ratio of 44:1)

5.5.2 Technology and sources of procurement

The current project has utilized modules and charge controllers from the USA, and battery and other components from local suppliers. It has been observed that the modules have managed to create a brand-image and customers are willing to pay a premium for them. The source of rest of the components including the battery and charge controllers is of little relevance to them. The community has been using locally made battery and is fully aware of its cost and quality limitations. Although the users of DLS are happy with the better performance of the Exide battery, cost is the major deciding factor for its purchase and replacement.

Following the local market dynamics, and ignoring the cost implications of importing modules, it would be best to use modules from USA for all proposed interventions. Further, a mix of crystalline and thin film modules would offer an opportunity to evaluate the techno-economic advantage of the latter. The market with its increasing size and commercial maturity, may provide a segment where thin–film technology can make the systems affordable to many more potential customers.

All the other components should be procured locally. During the initial stages, RKM can purchase components from other suppliers, but for sustenance of such interventions, it would help RKM to develop in-house capabilities to design, assemble and repair components such as charge controllers, luminaires and inverters.

5.5.3 Developing the institutional mechanism

The current project, executed by the R K Mission, is a collaborative effort between NREL and MNES. MNES, in addition to providing partial funding to the project, has been guiding and ensuring the project execution as per the plan.

For proposed interventions, MNES's role is envisioned as an institution who will guide, facilitate and internally monitor the implementation with following specific activities:

- Review of all business plans
- Facilitation in conducting training programmes
- Scrutinizing the utilization of revolving funds
- Matching grant for new initiatives as proposed in section 5.4

R K Mission has executed the project through a three-tier approach. Rupayan's role is most crucial in this structure because of its position at the second-tier, which requires coordination with the rest two tiers. Although Rupayan has faced several problems with respect to its professionals, internal funds, management issues etc, it would not be advisable to alienate Rupayan from proposed interventions at this stage. Rupayan has gathered valuable experience in terms of marketing, sales, after sales, payment collection etc. over the past few years through the execution of this project. This experience would provide a strong foundation for strengthening the institution for undertaking proposed interventions in future in this block, and to transfer the knowledge to others.

Specific to the proposed interventions in this study, RKM/ Rupayan has to develop a detailed business plan based on an elaborate planning exercise. The business plan should provide individual road maps for implementing proposed interventions, identify contingencies and prepare Rupayan for the same. Through the business plan, RKM/ Rupayan will be expected to make time bound infrastructural and financial commitments, which would also help MNES and NREL in effective monitoring of the project as well as a timely knowledge of their required intervention. The business plan for this project should be independent of their other plans, to the extent possible ensuring that their other activities/ constraints do not interfere much with the proposed activities.

RKM/ Rupayan may take help of other experts in making the business plan.

For providing additional lighting systems to new Youth Clubs, a cluster approach should be followed to maximize the impact on the community in a particular region. This would also ease the maintenance of systems in future. If successful, this model which aims at benefiting the community in a cluster through SPV powered community centres (Youth Clubs) could be replicated in other regions.

5.6 Business oriented approach for sustaining the interventions

An option is worked out in this section which addresses the issue of long-term sustenance of the intervention by involving commercial entities in the implementation process, thereby supplementing the efforts of R K Mission. An example of solar lantern charging-cum-renting shops as discussed in section 5.3.2 is taken to elaborate upon the suggested option.

The solar lantern renting shops are an alternative to the diesel generator owner who sets up temporary generation and distribution systems for electricity at the site of requirements. There are many entrepreneurs[9] who are in this business. These businessmen will perceive the new intervention as a threat to their business and would probably offer resistance to the its popularization.[10]

An insight into their business and preliminary calculations (presented in the box below) show that even after selling electricity at the rate of Rs 10 per kWhr, they earn on an average Rs 2 500 per month.

[9] The exact number is not known, but estimates put this number as 15 in the region.
[10] Drawing conclusions from the case of Rupayan battery charging station

Dynamics of diesel generator based electricity supply	
Generator rating	10 kVA
Percentage of loading	100
Selling rate of electricity	Rs 10 per kWhr (electricity to a 100 watt bulb for 5 hrs. for Rs 5)
Hours of operation in a day	5 (demand is only in the evening for lighting)
Days of operation in a month	25
Electricity supply in a month	1250 kWhr
DG operation and maintenance cost per month	Rs 10 000 (417 litres of diesel requirement @ Rs 16/litre, additional cost for mobil oil, transportation cost etc.)
Income from sale of electricity	Rs 12 500 (Rs 5 per day from 100 consumers for 25 days in a month)
Net profit	Rs 2 500 per month

One of these entrepreneurs can be selected as a partner to RKM in managing the business at village level in a manner that the charging station may be owned by the RKM which leases the facility to its partner at a fixed monthly amount. In section 5.3.2, it has been shown that the monthly collection from these shops would be Rs 3 375 per village if the lanterns were rented out for only 15 days in a month. If the entrepreneur manages to rent these lanterns for 25 days in a month, a total of Rs. 5 625 can be generated per month. Out of this generation, upto Rs 4 000 can be his earnings, Rs 1 000 can be the renting charges which he pays to RKM, and remaining Rs 625 is kept aside for maintenance requirements.

The above model is an indication that the economics, if worked out in details, can be shown to be favourable to support such a model which addresses the issues of strengthening the institutional model for this intervention by involving existing business entities. It targets the overall sustainability of the approach.

Annexure 1

The Sunderbans: Geographical and meteorological data

Area	:	9629 sq. km.
Latitude	:	21°32'N to 22°37'N
Longitude	:	88°02'E to 89°05'E
Population	:	2.9 million
No of blocks	:	19
Average Annual Solar radiation	:	1600 kWh/m²
Average Annual Wind Speed	:	14 kmph to 18 kmph
No of Sunny days in a year (Av)	:	250
No of partial Sunny days in a year (Av)	:	60
Totally Overcast days in a year	:	55
Soil condition	:	Soft / Saline
Temperature	:	38°C max/ 10°C min

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13. ABSTRACT *(Maximum 200 words)*
This report has been prepared by the Tata Energy Research Institute (TERI) for the National Renewable Energy Laboratory. It presents the results of the evaluation and impact assessment of solar photovoltaic lighting systems in the region of Sunderbans, West Bengal, that were deployed by a reputable non-governmental organization (Ramakrishna Mission) under the auspices of the INDO-US collaborative project. The objectives of the study were to evaluate the solar photovoltaic systems for their impact on the individual households as well as on the community, to assess the effectiveness of the implementation and financial mechanisms, and to draw a long-term strategy for NREL's activities in Sunderbans based on case studies of similar interventions. Under the project, provision was made to supply 300 domestic lighting systems (DLS) based on 53-Wp module capacity to individual households and a few other systems such as for lighting, medical refrigeration, and pumping water to community centres. For this study, 152 households were surveyed, of which 29 had also been a part of earlier pre- and post-installation surveys, 47 had been a part of the earlier post-installation survey, and 76 were new households that were surveyed for the first time. A set of 46, out of the total 152 households, was selected for evaluating the systems for their technical performance with respect to module output, condition of the battery, and daily energy consumption. Of the total 300 modules, 2 had been stolen, 9 out of the total 300 batteries needed to be replaced, and 10 out of the 300 charge controllers were non-functional. The statistics for the surveyed households indicate 32 luminaire-related faults (blackening or flickering of compact fluorescent lights) and 11 other faults related to fuses, switches, etc. The households have found the DLS useful in several ways: the light makes it possible for children to study even after daylight hours, it deters thieves, and the family can watch TV. There is a demand for additional light points or a higher capacity system by 73% of the surveyed households. Due to the increase in family size, 56% of households want to purchase additional systems. One of the most significant advantages of DLS, as reported by 93% of households, is security against thefts. Consumption of kerosene, which was the only source of lighting in the households prior to DLS, has been reduced by 7 litres per month on an average. Because the households are now able to meet 50% or more of their demand from the kerosene bought from the Public Distribution System at Rs 3.50 a litre, there is a substantial saving in monetary terms as well (from Rs 72.3 to 32.64 per month on average in one of the villages). Most of the batteries were found to be in good physical condition with respect to casing, battery terminals, and battery boxes. The average daily ampere–hrs received by the batteries is in the range 10–15, whereas the consumption is about 10 ampere–hrs daily. Illumination was inadequate for reading in a few households. Each DLS customer was expected to pay about 50% of the total cost of the system through a financing scheme (Rs 3500 as a down-payment and Rs 3600 to be paid in 60 equal monthly installments). Payment collection has been 88% to date.

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