IEA INTERNATIONAL ENERGY AGENCY

16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

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International Energy Agency
Implementing Agreement on Photovoltaic Power Systems

Task 9
Deployment of Photovoltaic Technologies:
Co-operation with Developing Countries

16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries

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FOREWORD

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme is one of the collaborative R&D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. Currently activities are underway in five Tasks.

The 21 members of IEA PVPS are: Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), European Commission, Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), the United Kingdom (GBR), and the United States (USA).

The objective of Task 9, which started in May 1999, is to increase the overall rate of successful deployment of PV systems in developing countries, through increased co-operation and information exchange with developing countries and the bilateral and multilateral donors.

Thirteen countries[1] participate in the work of Task 9, which is an international collaboration of experts appointed by national governments and also includes representatives of the World Bank and United Nations Development Programme. Developing country representatives are invited to participate.

This report has been prepared under the supervision of Task 9 by:

Z. Li, R. Gunning, R. Oldach and K.Syngellakis	*IT Power, GBR*
G. Stapleton	*GSES, AUS*
H. Muller and R. Posorski	*GTZ, DEU*
H. Tikkanen	*NAPS Systems Oy, FIN*
A. Shanker	*IED, FRA*
Takayuki Tani	*IEEJ, JPN*
Hideo Senba	*Shikoku Research Institute, JPN*
Takayuki Nakajima	*Japan Photovoltaic Energy Ass, JPN*
FP van der Vleuten	*Free Energy Europe, NLD*
A. Arvidson	*SEI, Sweden*

in co-operation with experts of the following countries: Canada, Denmark, Finland, France, Germany, Italy, Japan, Sweden, Switzerland, and the United States of America. Each case study expresses the views of the individual authors and does not necessarily represent a consensus of opinion of Task 9 Experts. This document is one of a series being published by Task 9. The complete series of documents comprises:

- PV for Rural Electrification in Developing Countries – A Guide to Institutional and Infrastructure Frameworks.
- Summary of Models for the Implementation of Photovoltaic Solar Home Systems in Developing Countries.
- PV for Rural Electrification in Developing Countries – A Guide to Capacity Building Requirements.

[1] Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom, the United States of America.

- Financing Mechanisms for Solar Home Systems in Developing Countries: The Role of Financing in the Dissemination Process.
- The Role of Quality Management, Hardware Quality and Accredited Training in PV Programmes in Developing Countries.
- PV for Rural Electrification in Developing Countries - Programme Design, Planning and Implementation.
- Sources of Financing for PV Based Rural Electrification in Developing Countries.

SCOPE AND OBJECTIVE

This document describes 16 case studies of the deployment of photovoltaic (PV) systems in developing countries. In PV system deployment, whether by commercial means or through an organised government or donor programme, the nature of the institutional and financial framework, the implementation and financing mechanisms used and the level of capacity building and quality assurance affect the success of the PV deployment. The case studies offer examples of different deployment structures, highlight success factors and lessons learnt from each experience and stress the influence of local circumstances in each country and region.

This guide should be useful to all the decision-makers in the process of developing a PV project, be they bilateral and multilateral institutions, host governments in developing countries, PV project developers and sponsors, PV producers and suppliers, entrepreneurs, or NGOs. The case studies presented can help decision-makers learn from past experiences of PV deployment, in particular with regard to the institutional framework, financial mechanisms and implementation models. As well as these themes the case studies can also offer examples of the overall process of project planning, design and implementation.

The guide should be read in conjunction with the following six guides, also developed by Task 9 and published by the IEA PVPS. These are:

- Institutional and Financial Infrastructure Framework for PV Deployment in Developing Countries;
- Summary of Models for the Implementation of Photovoltaic Solar Home Systems in Developing Countries - Part 1: Summary and Part 2: Practical Experience;
- The Role of Quality Management, Hardware Quality and Accredited Training in PV Programmes in Developing Countries;
- Financing Mechanisms for Solar Home Systems in Developing Countries: The Role of Financing in the Dissemination Process;
- PV for Rural Electrification in Developing Countries – A Guide to Capacity Building Requirements;
- PV for Rural Electrification in Developing Countries - Programme Design, Planning and Implementation.

Although this document focuses on PV systems, many of the issues that are discussed in the case studies are equally applicable for other technologies. This document does not cover the detailed technical aspects of PV systems or the issue of recycling old batteries. It should also be noted that in a number of developing countries, the bulk of the PV market comes from “professional” applications – relatively large scale applications such as telecom relays, remote army and marine applications. These applications are not covered by this document.

KEYWORDS

Keywords: developing countries, PV, deployment, solar home systems, institutional infrastructure, financing, capacity building, implementation, quality assurance.

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ABBREVIATIONS AND ACRONYMS

A	Amp
ABET	Adult Basic Education and Training
AC	Alternating Current
Ah	Ampere hour
AU	Administration Unit
AusAID	Australian Agency for International Development
AV	Audio Visual
BMZ	German Federal ministry for Economic Cooperation and Development
BOS	Balance of System
CDER	Centre de Développement des Energies Renouvelables
CEB	Ceylon Electricity Board
CER	Cumulated Energy Requirements
CFL	Compact Fluorescent Lamps
CILSS	Comité Inter-Etat de Lutte contre la Sécheresse au Sahel
DC	Direct Current
DME	Department of Minerals and Energy
DOE	Department of Energy
DoE	Department of Education
DSC	District Service Centres
EMT	External Management Training
ESCO	Energy Service Company
ESD	Energy Services Delivery
ETC	Economic and Trade Commission
EU	European Union
EWs	Extension Workers
FAO	Food and Agriculture Organisation
FSP	Foundation of the peoples of the South Pacific
FY	Financial Year
GDP	Gross Domestic Product
GEF	Global Environment Facility
GOC	Government of China
GSES	Global Sustainable Energy Solutions Limited
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
GWh	Giga Watt hour
IFC	International Finance Corporation
IMF	International Monetary Fund

IREDA	Indian Renewable Energy Development Agency
ISP	Institute for Sustainable Power
JICA	Japan International Co-operation Agency
KCB	Kenya Commercial Bank Group
KVA	Kilo Volt Ampere
KW	Kilowatt
LED	Light Emitting Diode
LPG	Liquid Petroleum Gas
LV	Low Voltage
MAD	Moroccan dirhams
MOA	Ministry of Agriculture
MOF	Ministry of Finance
MOST	Ministry of Science and Technology
MV	Medium Voltage
MW	Megawatt
MWp	Megawatt peak
MRO	Ouguiya (Mauritanian currency)
NAD	Namibian Dollar
NBFI	Non Banking Financing Institution
NDC	Namibian Development Corporation
NDP	National Development Plan
NGO	Non Government Organisation
NORAD	Norwegian Agency for Development Cooperation
ONE	Office Nationale de l'Electricité, Morocco
PCI	Participating Credit Institutions
PERG	Global Rural Electrification Programme
PIU	Project Implementation Unit
PMO	Project Management Office
PMU	Project Management Unit
PV	Photovoltaic
PVMTI	Photovoltaic Market Transformation Initiative
PVP	Photovoltaic Pumping
QC	Quality Control
QNERI	Qinghai New Energy Research Institute
RDP	Reconstruction and Development Programme
RE	Renewable Energy
REFAD	Renewable Energy for African Development
RERED	Renewable Energy for Rural Economic Development Programme
RFP	Request for Proposals
RO	Reverse Osmosis
RSC	Regional Service Centres
RSP	Region Solar Programme
SACCO	Savings and Credit Cooperative Society
SADC	South African Development Community
SADCC	South African Development Co-ordination Conference
SAZ	Standard Association of Zimbabwe
SDC	Solar Development Corporation
SDPC	State Development and Planning Commission

SEC	Solar Energy Company
SEEDS	Sarvodaya Economic Enterprises Development Services
SEIAZ	Solar Energy industries Association of Zimbabwe
SELF	Solar Electric Light Fund
SEPA	State Environmental Protection Agency
SETC	State Economic and Trade Commission
SHS	Solar Home System
SIA-SL	Solar Industry Association of Sri Lanka
SYP	Syrian Pound
SPIRE	South Pacific Institute for Renewable Energy
SPLC	Solar Power and Light Company
SRI	Shells Renewables India
SSAEL	Shri Shakti Alternative Energy Ltd
TAU	Technical Assistance Unit
UNDP	United Nations Development Programme
UNPEDP	United Nations Pacific Energy Development Programme
USAID	United States Agency for International Development
USD	United States Dollar
V	Volt
VCR	Video Cassette Recorder
Wp	Watt peak
WSS	World Solar Summit 1996
XOF	Franc Africain
ZWD	Zimbabwe Dollar

SUMMARY

PV has considerable potential to contribute to meeting the energy needs of rural and remote communities in developing countries. This document describes 16 PV deployment programmes in developing countries. These case studies provide experiences and lessons learnt on the importance of an appropriate institutional and financial framework, of sufficient capacity building and quality assurance and of choosing the right implementation and financing mechanisms to ensure the development of a sustainable PV market. Table 1 on the next page gives a summary of the experiences of each case study in relation to each one of these aspects.

The 16 case studies summarised in this document cover deployment of PV technologies in 27 countries. These countries are: Kenya, Morocco, Mali, China, Kiribati, Mozambique, Namibia, Zimbabwe, Zambia, Syria, Chile, India, Argentina, Brazil, Indonesia, Jordan, the Philippines, Tunisia, Burkina Faso, Cap Verde, Chad, Gambia, Guinea Bissau, Mauritania, South Africa, Niger and Senegal. The views in each case study reflect those of the author.

Nearly all of these case studies refer to programmes set up between the host country and bi-lateral and multi-lateral donor agencies and institutions. These agencies and institutions include, amongst others, the World Bank, the European Commission, the Global Environment Facility (GEF), JICA, GTZ and other bi-lateral agencies, national governments and institutions and local counterparts. However, one case study refers to purely commercial (market-driven) sales of PV systems in Africa.

Some case studies cover a programme implemented in just one country, others like the African commercial case study, PVMTI programme and PV Pumping case studies, concern programmes that cover several countries. These case studies serve to highlight differences in the same programme between different countries, depending on local conditions.

The deployment of PV often focuses on Solar Home Systems (SHSs) however a considerable proportion of the PV market in developing countries consists of larger systems providing electricity for social services and economic activities. Some examples of PV deployment to facilitate social services are:

- light for schools, mosques, churches, communal centres, etc;
- light and refrigeration for health centres;
- pumping and desalination for drinking water for communities.

Applications of electricity generated from PV used for economic activities include pumping and desalination for irrigation in agriculture and animal herding. This document includes case studies covering deployment of PV for social as well as economic purposes.

There are considerable differences between the ‘social market’ and the private market for SHS. The ‘social market’ generally consists of larger sized systems but fewer in number. In most cases, donor organisations are involved and the clients are not individuals but social entities (schools, health clinics, etc) that have different legal status and organisational characteristics.

In Section 1 of this document some of the experiences and lesson learnt from the case studies are highlighted in each of the six areas of institutional framework, capacity building, implementation models, financing solar home systems, quality assurance and programme design, planning and implementation. The 16 case studies are presented in Section 2.

Table 1. Summary of the experiences of the case studies with regard to the Task 9 document subject areas

Country / Countries of PV Deployment	Title of Programme / Project	Institutional Framework	Capacity Building	Implementation Models	Financing SHS	Quality Assurance
Kiribati	PV Rural Electrification in Kiribati	x			x	
Morocco	Decentralised Rural Electrification Case Study of Morocco: The First Large-scale Experiences	x		x	x	
Argentina, Brazil, Indonesia, Jordan, the Philippines, Tunisia, Zimbabwe	Drinking Water Supply with Photovoltaic Water Pumps (PVP)	x		x		
China	GEF / World Bank Assisted China Renewable Energy Development Project PV Component	x	x	x	x	x
Zimbabwe	JICA PV Project - Case of Zimbabwe			x	x	x
Burkina Faso, Cap Verde, Chad, Gambia, Guinea Bissau, Mali, Mauritania, Niger, Senegal	Lessons from the Regional Solar Programme (RSP) in the Sahelian countries	x	x			x
Namibia	Need, Policy, Market Development: PV-Dissemination in Namibia			x	x	
South Africa	PV Electrification of Rural Schools in South Africa	x	x	x		x
Chile	Resource-Conserving Irrigation with Photovoltaic Pumping Systems in Chile			x		
Syria	Water Desalination Powered by PV System in Syria	x				
Mozambique	Solar Energy for Health Improvement in Mozambique	x	x	x		
China	Solar Energy for Village Electrification in China	x	x			x
India, Kenya, Morocco	The Photovoltaic Market Transformation Initiative	x		x	x	
Morocco, Mali, Kenya	The Take off of the African Commercial PV Sector				x	x
Sri Lanka	The World Bank Energy Services Delivery Project: Credit Programme and Capacity Building - Solar Home Systems	x	x	x	x	x
Zambia	Rural PV Electrification through Energy Service Companies in Zambia	x	x	x	x	x

Note: PV programme design, planning and implementation is integral to each programme.

SECTION 1 - INTRODUCTION

These 16 case studies formed part of the information source for the formulation of the following guides:

- Institutional and Financial Infrastructure Framework for PV Deployment in Developing Countries;
- Financing Mechanisms for Solar Home Systems in Developing Countries - The Role of Financing in the Dissemination Process;
- The Role of Quality Management, Hardware Certification and Accredited Training in PV Programmes in Developing Countries;
- PV for Rural Electrification in Developing Countries - A Guide to Capacity Building Requirements;
- Summary of Models for the Implementation of Photovoltaic Solar Home Systems in Developing Countries - Part 1: Summary and Part 2: Practical Experience;
- PV for Rural Electrification in Developing Countries - Programme Design, Planning and Implementation.

Section 1 summarises the experiences and lesson learned from the case studies in relation to the topic areas of these six guides. The case studies are presented in Section 2. The views in each of the case studies reflect those of the author.

1.1 Institutional and Financial Infrastructure Framework

The institutional and financial infrastructure framework covers a wide range of issues that includes the role of government, the legal framework, market barriers, technical capacity, use of local institutions such as non-governmental organisations (NGOs) and the role of the private sector. Market forces and government programmes both play their part in promoting the adoption of PV in developing countries today. However, widespread opinion across a broad range of actors recognises a clear need to strengthen the institutional and financial framework in support of the long-term market development and deployment of PV to global rural communities.

This requires the adoption of a lifecycle approach and a re-emphasis on the provision of a sustainable service. Too many past PV projects have resulted in early system failure with inadequate provision for rectification. In such incidences, consumer disillusionment and negative press have been the natural consequence, to the detriment of the wider adoption of PV technology.

There are two general approaches to PV deployment in developing countries:

Direct sales to customers (commercial). This is roughly an unrestricted market in which PV dealers and developers conduct direct sales. The product sold is composed of a solar home system (SHS) purchased by individual households. Several countries in Africa have developed a PV sector that supplies household solar energy systems on a strictly commercial basis.

Rural electrification programmes and rural development programmes where PV has a role to play. Characterised by the fact that project developers and project managers are the principal actors deciding the products and prices in the market. The product range usually varies between PV mini-grids, large-scale SHS implementation programmes and PV for the following public and social end-uses: telecommunications, water pumping, refrigeration, and lighting for schools.

However, the influence of programmes on the commercial PV sector of a country can be difficult to predict. In China, the direct subsidy to the PV companies in the framework of a rural electrification programme did stimulate the SHS market, however, it also had a negative influence on the market where it was already commercially operated.

It can be seen from the case studies that at the institutional level the issues that need to be addressed are:

- Regulation and the Public Authority. The positive role of Public Authorities and the Regulator is significant yet requires further development in practice;
- How to create an enabling environment for the key roles of end-user or end- user groups, the service provider, and the independent facilitator to act as mutually supportive agents;
- PV lifecycle (in the context of either the open market or government sponsored programmes) and in particular the need to develop provision of:
  1) After-sales services through service providers;
  2) Consumer awareness programmes as well as mechanisms to empower consumers either individually or through the facilitation of consumer groups;
  3) Standards and accreditation schemes to ensure appropriate system quality, installer and maintenance personnel.
- How to define the role and harness the value of NGOs.

As demonstrated in the case studies, the establishment of a long-term sustainable PV market in developing countries depends primarily on the success in building an appropriate infrastructure framework with distribution, financing, installation and an after-sales structure. Once an institutional and financial framework exists in which a sustainable PV market can be established this in turn will offer assurance to end-users.

When governments, donors and utilities install grid power systems they make sure that they have the means to operate, maintain and regulate them – this is equally relevant to PV systems. All forms of electricity generation require financial resources and management, and operational structures.

Good examples of remediation action taken at the institutional level, after system failures appeared, are demonstrated in the case studies on Kiribati and South Africa. In both cases the result was a more successful PV deployment programme.

1.2 Financing Solar Home Systems

The lack of financial services for users of Solar Home Systems (SHS) is often regarded as the main barrier for their commercial dissemination and is often the justification for donor assisted programmes. The case studies shed some light on the question of whether commercial SHS dissemination in remote rural areas could be made easier if financial services were available. In many of the case studies new financial services have been created to fit into existing financial structures, in order to be sustainable once a programme has finished and to avoid distortions of local financial systems.

It is clear from case studies and general experience that formal and informal financial intermediaries alike only offer SHS credits in exceptional cases. Even in the micro-finance sector there are relatively few known examples where SHS financing has been provided with any consistency. Although the SHS target group partly comprises the same microfinancing institution clientele, SHS are still not simply incorporated in the credit programmes offered.

Alternative types of dissemination and financing are operating in various countries. The promoters are PV dealers and suppliers, but also other potential distribution channels such as the retail trade. However, the interest rates charged are often prohibitive for rural populations. By refinancing the retail dealer / supplier, commercial banks are also participating in SHS activities, even though only indirectly and with a limited amount of risk.

The case studies show that projects are learning from the experience of the past, and include the creation of more affordable types of financing models for the dissemination of SHS in the project objectives (eg. the micro-finance institution SEEDS in the Sri Lanka PV programme).

The case studies also show some results that differ from commonly held views. For example, customers are often prepared to pay more on a monthly basis to own an SHS than they were previously paying for kerosene and battery lighting. This is partly due to the higher quality light provided by the SHS.

Factors that contribute to a poor credit repayment performance are technical unreliability, a less than assured durability of vital components (e.g. battery), and also lack of awareness of the known limitations of the SHS by the end-users. The end-user needs to be not only capable of coping with the repayment of credit, but also with considerable operating costs that follow the purchase of a SHS. This highlights the fact that for the poorest segments of the rural population the SHS is a technology that is still often not affordable, even with subsidies and smaller systems. One example of lack of deployment penetration to the rural poor can be found in the Namibia case study.

There are few instances of the classic problem of the past of lost, stolen or broken systems, suggesting that even though there are still significant improvements that have to be made, PV deployment programmes are learning from past lessons. This has to be done by providing a financing mechanism that provides for operation and maintenance costs and an implementation model that deters selling on systems and thefts. A good example of this can be found in the Rural PV Electrification through Energy Service Companies in case study from Zambia.

1.3 Capacity Building

Capacity building activities for all levels of project participants can be essential to the successful implementation of a PV project. This is demonstrated in the case studies.

Successful project implementation is closely linked to the readiness, preparation and available capacity in the institutional infrastructure of a country for a PV deployment project. Project implementation can be delayed or postponed for several years due to national institutional co-ordination issues, a situation which can have a devastating effect for commercial actors involved in the project, such as PV companies that had agreed to participate in the project. Delay in project implementation discourages private companies, especially small local companies from participating in projects and thus should be avoided at all costs.

In the framework of a PV deployment programme, capacity building activities include:

- Providing training to project staff and government officials on project implementation and management, including project monitoring and evaluation.
- Providing business training and business consultant services to increase the commercial capabilities of local PV companies;
- Capacity building for quality assurance; and
- Public information campaigns to give consumers objective information about PV systems.

At the very minimum, capacity building should focus on those that will be using the system on a daily basis and who will be responsible for its maintenance. In the case of a health centre this will be the staff and in a household this will be the occupant.

In China, capacity building activities were undertaken at the project preparation stage in order to strengthen institutional capabilities for PV quality assurance, project management and public awareness and to increase the commercial capabilities of the PV companies. There is evidence of a strong link between capacity building and the effective application of quality standards and smooth implementation of a project.

The impact of capacity building activities is to greatly improve the commercial capabilities of small PV companies. Small-scale PV companies often lack commercial capabilities, which makes it difficult for them to get a loan from a commercial bank or to develop a business plan. Projects offering business training workshops and business tutoring services including financing, accounting and business development plans for local PV companies increase their chance of success in creating a sustainable market for PV systems.

A further issue highlighted in the case studies is capacity building for the PV system installers and end-users. In addition to training the installers the initial training programme needs also to include plans for updated re-training and continued training of the local users. This has proved to be necessary in order to prepare for new people moving into the area or trained people leaving the area, as well as re-training for the maintenance staff / responsible persons..

The quality and quantity of instruction given to installers and end-users must be recorded and assessed. Only in this way can it be improved progressively. In the case of "social "use of PV systems such as schools or health centres, the case studies suggest that constant re-training of the staff with regards to operation and maintenance is important, particularly during the first 2 or 3 years after installation in order to ensure the best possible exploitation of the PV systems.

The studies confirm that a local institution must take charge of the long-term re-training and updating the training material if necessary. Programmes partly or entirely funded by foreign agencies must make provision for this in the programme preparation phase to ensure a smooth hand-over of responsibilities to local actors. This could mean ensuring local staff have the capacity to train new staff.

When a PV deployment programme is due to come to an end, planning and preparation must be carried out in order to pass on the responsibility for the training to the appropriate local institution after the end of the funded programme. In the case of PV systems installed in health centres in Mozambique, it was the Ministry of Health which was best placed to assume the responsibility for training and re-training clinic staff.

1.4 Quality Assurance

Quality Assurance activities are important in ensuring that a long-term sustainable PV market is established. For a PV implementation programme, or indeed any rural electrification programme, there are three important areas of quality control:

- quality management – which the covers the operational procedures of the organisations involved – from PV system installers and hardware suppliers to financiers and service providers.
- technical standards – compliance with technical standards provides a degree of assurance that components meet agreed performance criteria .
- quality of training – ensures that system design, installation, commissioning and maintenance personnel have been trained to an agreed level of ability.

The case studies suggest that to some extent the PV market is slowly developing its own in-built quality control system. Panels that have a very high failure rate are not bought again and customers will choose another brand that has a better reputation for good quality in the field. However, the ability of consumers to make an informed judgement depends on the information available to them and the end-user capacity to understand available information. This factor varies greatly between and within countries. Often urban consumers are much better informed than those in the countryside, whom the media and communications networks do not reach.

An important role of quality assurance in a World Bank funded project in China is highlighted in the case studies. The whole technical specification for the solar home system components (module, controller, DC/AC inverter and DC lights) was called ‘the World Bank Standard’ by the PV companies involved in the project. This turned into one of the major advantages for the PV companies qualified to the standard competing against others in the SHS market in western China. Prior to the project, there had been no regulated or comprehensive standard for SHS in the market. As the public lacked awareness of SHS quality, the market competition was based mainly on price . As a result, the quality of the systems was neglected and unreliable PV systems were destroying the confidence of the consumer market. The system standard and test procedure has greatly improved the PV systems' quality and is clearly essential to create a long term and sustainable SHS market.

The availability of good quality local spare parts needs to be clarified as part of the process to enable smooth replacement of faulty appliances, thus ensuring proper operation of the installed system.

Another quality assurance issue stressed in the case studies is one that often does not get as much attention as system specification and quality of components. It is the issue of transportation. Special attention should be given to packaging and transportability of the equipment. This particularly important when the PV systems are meant for remote villages, where access can be difficult and transport distances long.

1.5 Implementation models

The high capital cost of PV systems has created the need to develop new and innovative implementation models in order to encourage widespread affordability and acceptance of the technology. A range of different implementation approaches for SHS can be seen in the case studies, from direct sales to fee-for-service models.

The case studies describe implementation for SHS but also for larger systems. When developing a new market for SHS, it is vital that an informed choice on the most appropriate implementation model is made. The case studies describe many different implementation models, however, it is important to recognise that local conditions will demand tailored solutions and approaches. One model may work very effectively in one country but be fundamentally flawed in its application to another country or area. Some typical characteristics of the different models, their advantages and disadvantages, are presented in these case studies. For more examples on implementation models for SHS please refer to the guide: Summary of Models for the Implementation of Photovoltaic Solar Home Systems in Developing Countries, Part 2: Practical Experience.

The case studies also describe solutions for "social" applications such as health centres and schools. In these cases the government or a donor agency pay the capital cost of the system and a fund for operation and maintenance must be set up to ensure the long-term sustainability of the project. Again, this often involves fee collection from the end-user. In social applications, the implementation must place an additional emphasis on end-user involvement, community organisation and a structured framework for the operation for maintenance of the PV system.

When developing a new market for PV systems, it is vital that an informed choice on the implementation model is made. An inappropriate approach to the deployment of solar home systems will result in a failure to develop a sustainable market for PV. It is important to recognise that local conditions will demand tailored solutions and approaches, or combinations of the models described. A good example of this is the Morocco case study where 4 different types of implementation approaches were used.

It cannot be stressed enough that flexibility and pragmatism are crucial in developing a successful implementation strategy. Changes in approach may also be required as the scale of the project expands and the target area is widened. Therefore continual monitoring and evaluation is necessary.

1.6 Programme Design, Planning and Implementation

Planning for and developing a PV project or programme is a multi-phase challenge. Many issues need to be considered before implementation can begin. As many programmes in the past were not entirely successful, it is useful to learn from past experiences and this is one of the objectives behind the compilation of the case studies in this report.

In planning for PV programmes, decision-makers must carefully weigh the costs and potential social, personal, and national benefits that will accrue from different allocations of resources. In addition, they must put significant effort into assessing the needs to be addressed by a particular PV programme, consulting with stakeholders, analysing potential technological solutions, and then designing a solution that will yield the desired benefits at appropriate costs.

The case studies can give input to those project developers who are interested in implementing or improving support programmes for the deployment of solar photovoltaic systems for rural electrification by providing some examples of the process of planning and implementing a PV project. Figure 1 gives an overview of the activities carried out in each phase of a PV project.

Figure 1. Overview of the activities carried out in each of the different phases.

Figure 1 was taken from the Task 9 document: PV for Rural Electrification in Developing Countries - Programme Design, Planning and Implementation.

Preparation Phase

- National Policy Objectives
- Needs Assessment
- Stakeholder Consultation and Social Context Analysis
- Assessment of capacity requirements
- Identification of technical assistance requirements
- Technical Supply Options and Analysis

Design Phase

- Goals and Objectives
- Institutional and Policy Framework
- Schedule and Milestones
- Logistics
- Management and Project Team Functions
- Training/Capacity Building
- Financial Delivery Mechanisms
- Technical System Specification and Procurement
- Quality Assurance Aspects
- Information management System
- Provision for ongoing maintenance, replacements

Implementation Phase

- Quality Control, Management and Evaluation
- Information Management System
- Capacity building

Monitoring and Evaluation Phase

- Impact Assessment
- Project Evaluation

SECTION 2 - CASE STUDIES

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2.1 PV Rural Electrification in Kiribati

Case study prepared by Takayuki Tani, IEEJ, JPN

Introduction

Kiribati has a population of only some 80,000 on 33 dispersed islands in the Pacific Ocean. The main income of Kiribati depends on the fishery licence from the vast exclusive economic zone, about 3.5 million square kilometres, and other industry is very small. Therefore, it sometimes needs foreign aid to develop its national infrastructure.

From independence (1980), the government has focused on the electrification of the country but only some vicinities of its capital area have been electrified. According to the results of the preliminary study for electrification, they found the electric demand of rural areas is too small and distributed to recover capital investment for electrification. So the government decided to electrify those areas by distributed type small generation.

Kiribati is located in the centre of the Pacific Ocean and has an abundance of solar energy resources. Other renewable energies such as wind or hydro are not usable. Small diesel generation is one way of electrification but the transportation of fuel between islands and even within islands is not easy. Therefore, the Kiribati government decided to adopt photovoltaics for rural electrification.

Project Background

Initial PV Trial – Failure

The first attempt to introduce PV nationally dates back to 1984 when Solar Energy Company (SEC) was established by the Foundation of the peoples of the South Pacific (FSP), using USAID funding. SEC was formed as a private company and carried out the sales of PV systems or components and their installations. According to this plan, technical training for SEC staffs was done under the cooperation of the UN Pacific Energy Development Program (PEDP) and the South Pacific Institute for Renewable Energy (S.P.I.R.E). The trained staff were to be available not only for free technical consultation with users at the office but also for some maintenance services on the site with the necessary charge.

At first, this went well apparently. About 270 SHSs were sold to private customers and some larger systems were sold to government facilities. But PV sales became lower and lower every year and in 1989 SEC almost went bankrupt.

At this time SEC became a national company, 99% of its shares were transferred from FSP to the Kiribati government. The government still had a strong will to develop PV rural electrification and had responsibility for SEC. Therefore it requested the Forum Secretariat Energy Division to fund the survey of all the PV purchasers in order to identify the reason for the PV business decrease.

From the survey, they found that almost all the systems were not properly maintained, some were without maintenance, some were replaced with improper components, some didn't have their charge controllers, some panels were heavily in the shadow, etc. Average lifetime of those systems was less than three years. The purchasers' dissatisfaction was spread around the country resulting in a very negative reputation for PV, then PV sales dwindled within a few years after the project.

This means that a cash sales approach is not sustainable in Kiribati and the government and SEC decided to change the PV business model from sales style to utility style, what we call ESCO, with the recommendation of S.P.I.R.E.

The first attempt was indeed a failure but this very experience led Kiribati to succeed in PV rural electrification several years later.

Project Description

In 1990, the Japan International Cooperation Agency (JICA) did a study on implementing renewable energy programme in the South Pacific countries and as a result of the study, JICA and Kiribati agreed to carry out an institutional programme on PV rural electrification in the country. This time both JICA and Kiribati put a strong focus on implementing a sound institutional structure of ESCO style PV electrification, because of the experience of SEC's near bankruptcy. Only 55 SHSs were installed in the unelectrified villages of Kiribati's capital island of Tarawa, but the management system was deliberately and carefully implemented.

The system is described as follows:

- System hardware is composed of a 120 Wp solar panel with mounting pole and fitting structure, 100 Ah wet lead battery, charge controller, a 11 W fluorescent lamp, 9 W fluorescent lamp and interior wiring. Ownership of panel, battery and charge controller (power part) belongs to SEC and that of appliances and interior wiring (consumption part) belongs to users.
- Those who want to install the system must pay initial down payment of 90 AUD (1 AUD=0.5 USD) and monthly fee of 9 AUD.
- SEC can remove the systems of those who do not pay monthly fee more than 3 months continuously.
- SEC is in charge of the power part and users are in charge of consumption part, that is, SEC must maintain the power part such as battery water supply and replacement and users must take care of consumption part such as replacing troubled fluorescent lamps.
- Above responsibility is defined in the MOU between SEC and users before installation.
- A field technician is selected in the site. He is trained by SEC before the system introduction and must take care of the systems at the site at least once a month. He also must collect monthly fee from users.
- Field technicians are paid. SEC pays their salary from the collected PV fee.
- A senior engineer resides in SEC head office and takes care of field technicians. Twice a year he visits every site and deals with the more complicated technical problems which field technicians cannot deal with.

At first, some minor troubles happened. Some batteries run dry because the field technician neglected his duties. Old men in the village sometimes requested the field technician to share the collected fee for other public use according to their traditional custom of "give and share". Some families were deprived of their systems because of the outstanding fee payment. These troubles occurred in the first one or two years but all were arranged with the cooperation of SEC, users and JICA. From those experiences SEC gained the know-how that field technicians should be selected from amongst the reliable people in the village - usually people more than thirty years old who have some position in the community. Young men are good for absorbing technical knowledge but they do not have a high enough position in society to do their job against older men. In this respect the institutional aspect is very important in creating a sound management system.

Outstanding payments and system transfer is an unhappy situation for both the users and SEC, but strict execution of the contract is the most important way to establish a sound fee collection system. After several systems were actually transferred, no further outstanding payments occurred.

Seven years have passed, and all the systems now work well and the management system also works as planned. Most batteries came to the end of their useful life and they were all replaced under the supervision of SEC using the collected fee.

Project Impact

After the JICA project, another 250 SHSs were introduced through EU cooperation. Its management system was the same as the one developed by JICA, but this was another trial to test the sustainability in the remote islands. Most systems were installed in the outer islands and they also succeeded in setting up a sustainable management system.

By combining the JICA and EU projects, a total of 305 systems are now well operated and maintained in Kiribati. From these projects, a sustainable technical and institutional base for PV rural electrification was established in the country, leaving one important aspect - economic sustainability - still not established.

Currently the operation of the 305 systems brings a negative balance. The deficit is made up from the profit of other sections of SEC. SEC has three sections, one is the utility section which is in charge of the SHSs introduced by the two projects, another is the customer section which is in charge of installation and maintenance of independent users and the last is the manufacturer section which produces some peripherals of PV systems.

The Kiribati government is now introducing PV systems for its rural facilities little by little within its own budget, and some independent users such as churches, companies and individuals also install PV systems privately. All these systems are installed and maintained by SEC under the same ESCO style maintenance contract. When there is a large system installation, then this section makes some profit.

The charge controller produced by the manufacturer section has good reliability and is suitable for use in the salty wind environment of the islands. This technology was transferred from an EU consultant in the project. It has a good reputation and is sometimes exported to other countries bringing in some profit for SEC.

Even after all these efforts, the economic condition of SEC is not stable because of the constant deficit of the utility section. At this point it is important to reduce and clear this deficit. An EU consultant analysed the economics of the utility section, concluding that the number of SHSs should be expanded to 2 000 to get beyond the break even point. On the basis of this result, Kiribati and EU are now planning a new project of expanding to 1 500 SHSs with consultation for business improvement. However, a total of 1 805 systems is still just below the break even point. This means that the economic sustainability of SEC after the new project will depend upon whether or not the management capability of SEC is much improved by the consultation. Another effort is still needed for future success and it is on course to be realised.

2.2 Decentralised Rural Electrification Case Study of Morocco: The First Large-scale Experiences

Case study prepared by A. Shanker, IED, FRA

Project Aim and Objective

It is impossible to discuss decentralised electrification in Morocco without citing the Global Rural Electrification Programme (PERG). This scheme, launched by the Office National d'Electricité (ONE) in August 1995 and approved by the government of Morocco, has a threefold aim.

- Participatory: This programme was drawn up jointly with local *Communes Rurales (equivalent to local municipalities)* in rural areas, and it is carried out only with their consent and commitment to providing funding in the order of 20 %. The beneficiary households also incur roughly 25 % of costs. We will examine below solutions that have been adopted when rural governments are unable to fund their share.
- Geographical: This programme covers all the rural districts in the Kingdom. This aspect of PERG raises no major problems, insofar as the ONE grid covers practically all rural *communes*, excepting those served by multi "communes" water and electricity supply syndicates.
- Technological: The programme envisions two kinds of electrification, through grid connection or decentralised power. All types of technologies are used for decentralised power, but mainly those that rely on renewable resources.

It is PERG's ambition to boost the rate of rural electrification from close to 20 % in 1995 to 80 % by 2006, which means bringing electricity to more than 1 500 000 households in a little over ten years. Clearly this massive electrification can be achieved only by grid connection in the vast majority of cases.

Project Description

Project Infrastructure and Institutional Issues

The principal criterion of eligibility that has been chosen is the per-household cost calculated for each village, specifically in the perspective of grid connection. The databases required for these calculations have been compiled through fieldwork by a prospecting committee made up of the commune, the Local Authority and ONE. This procedure is designed to prevent objections to the data used. The maximum allowable cost figure determining eligibility for grid connection is 25,000 MAD[2]/household. This first criterion limits grid connection to fairly sizeable groups of households, and eliminates extremely isolated villages. A second criterion measuring the density of households within a village will be discussed below.

The programme is organised in tranches, by rising per-household cost. The second tranche currently being implemented (year 2000) is within the threshold of 10 000 MAD / household. PERG is thus implemented by Province, District and by year under a master plan drawn up by ONE, ensuring that each district president is informed of the provisional programmes planned for his jurisdiction.

Using this method, some 200 000 households have been identified as potential candidates for off-grid electrification. The decision of implementation, i.e. the programming of the installation, while benefiting from the PERG framework, is left to the initiative of either the Communes, or village associations. We will discuss below the strategy adopted in these cases.

To properly understand the following section, it should be underscored that the choice of the mode of electrification is not imposed by ONE, but is the outcome of negotiations, and perhaps

[2] 1 MAD = 9 cents USD

even a debate in the "Commune" council. ONE's role is limited to making proposals and recommendations pertaining to options supported by technical and financial studies. The partnership with the Communes is one of the most important features of the PERG concept, and we want to stress it. No PERG electrification project, regardless of the entities involved, can be undertaken without the assent of the Commune. This assent is materialised by an agreement drawn up between the two parties.

Project Financing

Here we would like to underscore that the financial contribution from the district, set at 20 % of the average cost resulting from a cost balancing mechanism at the national level, and discounted over the period of the PERG scheme, amounts to 500 MAD per household and per annum for a period of five years. In this way, the funds that the Commune must reserve for electrification can be budgeted in advance. This contribution is a set figure when the project is eligible for the ongoing tranche, i.e. when the preliminary study determines that the cost is equal to or less than the set ceiling. When the estimated cost is higher (and this is the case for projects that are not eligible for grid connection, among others) the Commune must pay the cost in excess of the ceiling.

This supplement must be paid in full before work begins. This payment is made in exchange for the advancement of the project or grid eligibility, and is incurred by the *Commune* if it so desires.

It is clear that the Commune president is likely to choose grid connection, for reasons that are often electoral. And if the cost is prohibitive, he may prefer to wait, rather than opting for decentralised power right away, even though this option is the least costly for the community. This attitude is further justified by the fact that Communes are generally made up of several villages, which may be of quite different population density; consequently they are given different treatment under the PERG scheme.

Project Implementation

- **Strategy Adopted**

The analyses carried out by ONE of the more than 36 000 villages in its database have highlighted one feature of rural settlement in Morocco: its low population density.

We announced an initial criterion to determine villages' eligibility for grid connection, i.e. a maximum per-household cost of 25 000 MAD. But this criterion gives no indication of the geographic dispersion of households within a single village. We therefore introduced a second criterion; namely the cost of the low-voltage network required to supply all the households in a village. On the basis of this cost we established a cut-off criterion that we set at 19,000 MAD per household. This criterion, which we feel is a good indicator of the dispersion of households, enabled us to identify 200 000 households for which grid connection is not advisable because it is costly. We have specified that these households are in villages that are not connected to the grid, and are not scheduled to be connected. For even in villages that are slated for grid connection, there may be outlying households that are distant from the village centre, and these are not considered in the estimation. These cases, although less frequent, give rise to a steady stream of protest.

The simplest solution and the one best suited to meet the objectives of large-scale decentralised electrification consists in equipping households with individual Solar Home Systems (SHS). This is also less expensive for the community. The main reasons are given hereafter.

Field surveys taken by ONE in a sample of rural grid-connected villages show that over 60 % of power consumption is devoted to household conveniences, primarily lighting and TV/radio appliances. Provided it is properly maintained, the SHS is perfectly well suited to this kind of use and is largely sufficient, given the limited needs of rural households.

The overall investment required for the SHS (including solar panel, battery, regulator, CFL lamps and accessories) is lower than that for conventional equipment, when connection costs and interior installation are taken into account.

The monthly bill for the PV installation is limited to reimbursement of maintenance costs, which are spread out over the period of the contract. Currently this bill varies between 50 and 100 MAD.

This equipment is now considered to be technically reliable, given the technological progress that has been made. The solar panel has an estimated useful life of over 15 years. As for the "solar" battery, with rational use, its useful life can exceed four years.

Now that the technological choice has been made, a number of management frameworks need to be worked out, their feasibility tested, and a large-scale PV action plan established. Our development strategy is built upon three strong points:

- Technical aspects: a complete standard SHS, ready to install, comprising a "generation" module made up of a 50 Wp panel, a battery and a regulator, and a "distribution" module made up of CFL lamps and accessories.
- Financial aspects: establishing a level of subsidy and payment schemes that are compatible with the financial resources of rural households.
- Organisational aspects: development of management frameworks or business models aiming at the sustainability of the PV service for a sufficiently long period of operation (at least seven years).

- **Initial small-scale pilot projects: direct action**

The reserved attitude of Commune Presidents toward PV energy constitutes one of the major problems we encounter in developing this type of electrification solution. This factor depends more on the surrounding context than on ONE's own capacities. It is easy for ONE to launch ambitious conventional electrification schemes, because of the utility’s natural monopoly as the only (or nearly only) operator of the medium-voltage grid in rural areas. But is much harder to set up a broad Decentralised Rural Electrification scheme.

Another difficulty stems from the specific nature of the mode we have selected, namely the PV SHS, for this product is considered as individual "domestic" equipment. It is therefore apprehended as private property, and is subject to the same rules of trade as other household goods (electrical appliances, for example). Furthermore, several other operators are active in equipping villages with PV systems, under various auspices: NGO acting under programmes providing assistance to village associations, aide from various outside entities involved in the development of poor Communes, etc.

We have undertaken the first projects by **direct action**. By this we mean operations conducted entirely by our own teams. The first households equipped are ONE customers, and ONE procures, installs and maintains the SHSs. ONE also handles billing of the monthly fees. The financial arrangement comprises:

- An advance payment of 1 440 MAD by the beneficiary household, and monthly payments of 60 MAD over a period of 7 years,
- A supplementary participation by ONE which covers the remaining equipment costs.

The initial pilot projects served as a test for our operational units, as well as publicising this mode of electrification to elected officials and households.

- **Second Approach: direct action with subcontractors**

This approach is a variant of the direct action approach, in which the installation, after-sales services and billing are contracted to a private company which is selected by competitive bidding and paid by ONE for its services. The number of households included under this approach exceeds 1 500, and is the result of work carried out jointly with village associations and the communes involved.

- **Third approach: partnerships**

Under this formula tasks are divided between ONE and a private company selected through competitive bidding.

- ONE provides the module and battery, and verifies that the project is properly executed and that customers get good service.
- The contractor provides the rest of the SHS, equipment installation, maintenance and after-sales service for a renewable period of 5 years.

The financial arrangements stem from this distribution of tasks. The ONE subsidy covers the cost of acquisition of the panel and the battery. The beneficiary household pays an advance and monthly payments (set by the terms of the tender) directly to the contractor.

This approach is being used for a scheme covering 7 000 households in a southern province. Close to 900 households had been equipped as of end of August 2000.

- **Fourth approach: fee for service**

The lessons learnt from these first three approaches are primarily:

- Technical: customer satisfaction achieved with the after-sales service;
- Financial: low and irregular bill recovery rate, the need to find payment modalities better suited to villagers' incomes;
- Organisational: the long delay between the customer's application and actual installation of the SHS is a handicap for the scheme. Stock management of equipment supplied by ONE is also a source of malfunction.

In light of this experience we have developed a new approach that is inspired by Anglo-Saxon "fee for service" systems. This scheme is summarised below.

Objectives:

1) Increase the pace of rural electrification by launching a tender for the installation of 20,000 kits over 5 years;
2) Open markets to competition throughout the country;
3) Encourage heavy involvement of the private sector.

Organisation: The contractor is chosen by competitive bidding on the basis of the lowest cost for services provided to households. The contractor provides all services, including supply and installation of all equipment. Needless to say, high quality of hardware and services is one of the requirements of the terms of reference. ONE pays receipts from users to the contractor. The period of the contract is set at 10 years.

Financial: The subsidy paid by ONE is set at 4 500 MAD per household equipped. The subsidy is paid directly to the contractor upon presentation of supporting documentation. The beneficiary household, customer of ONE, pays to ONE the advance and monthly payments set by the contractor with the lowest bid. Collection of payments is one of the services ensured by the contractor.

Ownership of equipment: ONE retains ownership of the "generation" unit and the household owns the interior installation.

Other features of this approach should be pointed out.

The contractor receives a list of villages that are potentially favourable to rural electrification, for information. The contractor is responsible for contacting new customers and promoting the product.

If several contractors are selected they may be in competition within a single region, or even within a single village.

The Commune involved and ONE sign an agreement authorising the electrification scheme within the limits of its territory.

To ensure the success of this project ONE is particularly careful in selecting contractors, who must submit tenders that meet ONE's requirements from an administrative and technical standpoint.

In our view this approach is likely to be highly successful, for the following reasons:

- It builds upon lessons learned from previous experience;
- It avoids the problems faced by Commune Presidents who must decide in favour of PV, and this is an important factor. In effect, with the contractor's marketing efforts aimed directly at the beneficiary households, the choice and decision centre will shift to households, and the president and / or Commune council will only have to show their approval.

To complete this overview of decentralised rural electrification, we will briefly mention some other projects undertaken for village electrification by isolated mini grids.

The first case is electrification by a diesel generating set. In most of these projects the service is conceived as pre-electrification prior to grid extension. The genset is re-used in other villages and the LV network remains. It should be noted that ONE undertakes few projects of this nature, given the operating costs and the resulting deficit for the utility, because the retail price per kWh is the same as for grid-connected customers. For the executed projects, ONE has devised a subcontracting scheme involving a young agent, chosen from the village, to hold down the costs mentioned above. However, we will not discuss this interesting case in greater detail here.

The second type of scheme involves other renewable energy resources. These projects are the following.

Mini hydropower plants: two sites, Agadir N'Ait Mhamed and Askaw, are being equipped on the southern slopes of the High Atlas range, at respectively 2 100m and 1 600m above sea level. The 200 kW and 300 kW turbines will supply MV and LV serving 63 villages with close to 1,600 households. The three Communes involved and the beneficiary households contribute to project funding under PERG. Electricity will be billed at the national kWh rate. Construction work has started and commissioning is scheduled mid-2001.

Two villages located on the Atlantic coast in the province of Essaouira have been equipped with wind turbines: a 25 kW unit serves 70 homes in Moulay Bouzerktoun; two 25 kW units supply 50 homes and a few small hotels in Sidi Kaouki.

This overview covers only projects already implemented or in the implementation phase. It is clear that the PERG design offers a remarkable degree of flexibility and openness. The proof is the wide range of formulas adopted and the significant volume of completed installations. Other projects are under study, including a portfolio of remote hydropower sites in mountainous areas. ONE draws upon the expertise of the Centre de Développement des Energies Renouvelables (CDER) which has provided invaluable support for PERG, in identifying zones with significant wind power potential, as well as assisting ONE in technical matters. The two organisations have signed a partnership agreement to formalise this support.

2.3 Drinking Water Supply with Photovoltaic Water Pumps (PVP)

Case study prepared by R. Posorski, GTZ, DEU

Introduction

The availability of clean drinking water is a basic human need. Nevertheless, World Bank estimates put the number of people in remote rural areas of developing countries with no access to clean water at roughly one billion.

Dirty and polluted water sources have a strong negative impact on health. Getting water from remote sites is troublesome and time consuming. Poor water supply contributes to the migration of rural people into overcrowded cities.

Consequently, government-sponsored programmes dedicated to the long-term improvement of drinking water supplies in rural areas are being conducted in numerous developing countries. Since most rural areas are not and will not be electrified for decades to come, national water authorities have to rely on diesel pumps in most of those programmes. Due to poor maintenance, breakdowns and lack of fuel, they are often out of service.

Here solar energy opens up new options for pumping water. Photovoltaic pumping systems require little service and no fuel. They can offer a reliable and environmentally sound alternative. Often, they constitute the only reliable solution to the problem of drinking water supply in remote areas. However, a lack of experience with PVP technology, as well as the comparatively high initial costs, has precluded its widespread application up to now.

Aims and objectives

The objectives of the PVP programme were to:

- Demonstrate the technical maturity of PVP;
- Determine the conditions for a cost-effective utilisation of PVP;
- Clarify the ecological benefits and the level of acceptance on the part of users and operators;
- Adapt PVP technology to the users need and to the climate conditions, the aim being to develop a marketable product;
- Clarify the opportunities for future PVP applications as well as their potential for dissemination.

Project Background

Due to the reliability of photovoltaic pumping systems a huge potential for dissemination in non-electrified, rural areas can be expected. In order to demonstrate the technical maturity of PVP and to clarify the prerequisites of a broad utilisation, the German Government funded an “International Field-testing and Demonstration Programme for Photovoltaic Water Pumps (PVP)”. The PVP programme was being conducted by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

The programme started in 1990 and was finished in 1998. It was followed by a second programme investigating the utilisation of PVP for irrigation[3].

The GTZ implemented the PVP Programme in co-operation with national energy and water authorities in Argentina, Brazil, Indonesia, Jordan, the Philippines, Tunisia and Zimbabwe. In the course of the PVP Programme, a total of 90 PVP systems have been installed at selected sites in the project countries. Those systems provide potable water to people of the village communities and their livestock.

Project Description

The PVP Programme analysed the opportunities for future PVP applications as well as their potential for dissemination. Consequently, the PVP Programme was designed primarily as a demonstration and field-testing programme, with water utilities and PVP suppliers/manufacturers as the main addressees. The results of the PVP projects provided a decision-making basis for:

- National or regional water utilities to assess PVP as a viable, least-cost option for rural drinking water supply, and
- PVP suppliers / distributors for product adaptation and marketing.

The overall idea was to achieve a major advance toward commercialisation of PVP technology by demonstrating its feasibility at a significant number of sites.

This was done in combination with thorough preparation of counterpart institutions and personnel, intensive interlinking with industry, and a comprehensive performance monitoring programme. The transfer of expertise to counterparts and of experience to the industry was crucial.

Key measures implemented have been:

- Site selection, ordering and commissioning of PVP systems,
- Monitoring the technical PVP operation and cost-relevant factors,
- Measures for community participation and sociological monitoring of the PVP communities,
- Training of water utilities' technical staff, planners and decision-makers,
- Adaptation of country-specific planning procedures,
- Promotion of technology and know-how transfer by involving national companies in the supply and maintenance process,
- Dissemination of project results and public relations work.

The conceptual approach behind the PVP Programme did not envisage competition between the PVP systems and hand pumps, wind pumps, grid-fed electric pumps or large diesel pumps. However, it regards PVP as an alternative to small diesel pumps at remote sites for communities with populations of 500 to 2000, since these usually experience:

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[3] A case study on the follow up programme "Resource-conserving Irrigation with Photovoltaic Pumping Systems“ is also available

- Low reliability of water supply due to irregular fuel supplies and frequent technical breakdowns;
- High cost of operation due to operator expenses, high specific fuel consumption and fuel costs, and major expenditures for repair and maintenance.

An attractive power range for PVP application lies between 0.7 and 4 kWp. Standardised, reliable components have been commercially available; including a suitable range of submersible AC motor pump units and inverters in the power range up to 4 kVA. For medium pumping heads of 50 m and daily insolation levels above 5 kWh/m^2, this power range of PVP can supply drinking water to communities with populations up to about 2000.

The typical PVP standard system consists of a PV generator, an inverter and a submersible motor pump that delivers water to a high-level reservoir (water tank). The water reservoir feeds the water by gravity to public water taps and watering points for cattle.

The PVP Programme concept promoted cooperation between the European equipment suppliers and the partner countries' local and national enterprises. As far as locally produced components of adequate quality were available at reasonable cost, they were incorporated into the PVP Programme in order to facilitate maintenance and spare-parts logistics while reducing the foreign currency input.

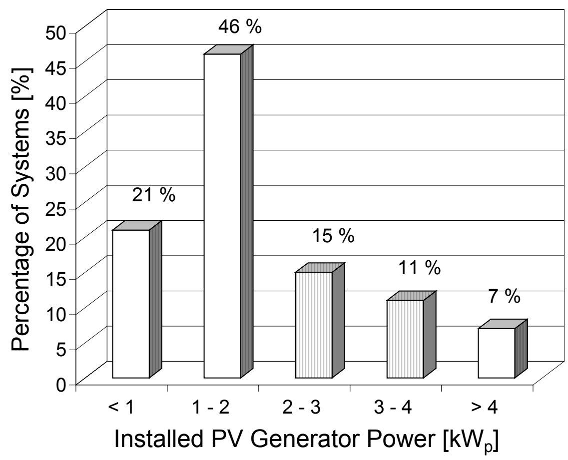
Community preparation and participation were considered integral parts of the programme, usually extending the institutional practices in the various project countries. Acceptance and social impacts were investigated thoroughly. On the technical side, a comprehensive monitoring programme was designed and carried out to gather all necessary data for evaluating the technical reliability and efficiency. A huge number of financial and economic data were collected and analysed in a couple of studies to judge the economic feasibility.

Lessons learned

Technique

A collective PV generating capacity of 185 kWp has been installed. Approximately 46 % of all systems implemented by the PVP Programme operate in the 1-2 kWp power range. The systems' operative range covers daily water discharge rates of 4 to 110 m^3. The pumping heads vary between 10 and 125 m.

In order to keep maintenance and repair as simple and inexpensive as possible, standard-type PVP systems incorporating commercially available components were selected. Besides the PV generator these include a submersible, multistage centrifugal pump equipped with a low-maintenance three-phase induction motor. An inverter converts the direct current (DC) provided by the PV generator into the requisite alternating current (AC) and serves as a system controller.



To compensate for daily and seasonal fluctuations of solar radiation, a suitable form of power storage must be included in the system. Conventional-type batteries are excluded since they tend to be maintenance-intensive and their service lives are limited to just a few years.

In PVP systems the pumped water is stored in a collecting basin or a high-level reservoir, which feeds the water by gravity to public water taps. The optimal storage capacity is roughly twice the daily water discharge rate.

This standard system has proved very reliable.
Despite the usual teething problems associated with the introduction of practically any new technology, an average availability of approximately 99 % has been measured for the 90 PVP

systems. The downtime was caused mainly by a total of 22 hardware failures, of which the inverters accounted for 70 %. Obviously, the inverter is still the most sensitive system component.

A rather new innovation is tandem systems that consist of two PVP installed at the same well. During periods of high insolation, when good pumping efficiency can be expected, the two plants operate in parallel with mutual independence. During periods of low radiation intensity, however, the two PV generators are coupled together to provide enough power to keep one pump running at a comparatively high efficiency. This concept allows utilizing low and medium solar radiation more efficiently. A one-year data evaluation of a PVP tandem at San Lorenzo, Argentina, proved a higher output of 16% compared to an independent operation mode.

While the high availability underlines the reliability of PVP, the failures that occurred show that PVP are not maintenance-free. The widespread introduction and diffusion of PVP products will require effective 'after-sale services' with local or at least national maintenance structures and readily available spare parts. Long delivery times for spare parts from abroad would cause unacceptable interruptions in the supply of drinking water.

Further optimisation of certain system components and establishment of a well-functioning local service structure, including stocks of spare parts, can be expected to further increase the availability of standard-type PVPs. In addition to the use of optimised system components, a crucial prerequisite for the reliability and economic efficiency of PV systems is an appropriate system sizing adapted to local conditions.

System design and sizing

In order to improve the design process different sizing procedures were compared with the systems' actual field data. Twenty-five different PVP systems were studied, all of which were equipped with automatic data acquisition systems. A pertinent method was developed to account for the daily run of insolation and, accordingly, the hydraulic output of the pumping system.

PVP systems are sized on the basis of the findings from a local data survey. The meteorological and climatic data are usually taken from the closest meteorological station to the site. Site data to be collected include water quality, water demand, pumping head and special geographical features, e.g. valley locus or shading. The pumping head and the demand are dynamic figures that may vary seasonally or in the long run.

Sociological factors are also a part of the planning process. Users should be involved in data collecting in order to make early allowance for their customs and traditions. For the project's long-term success, it is decisively important to fully inform the users on the targeted goals and any changes and improvements to be expected.

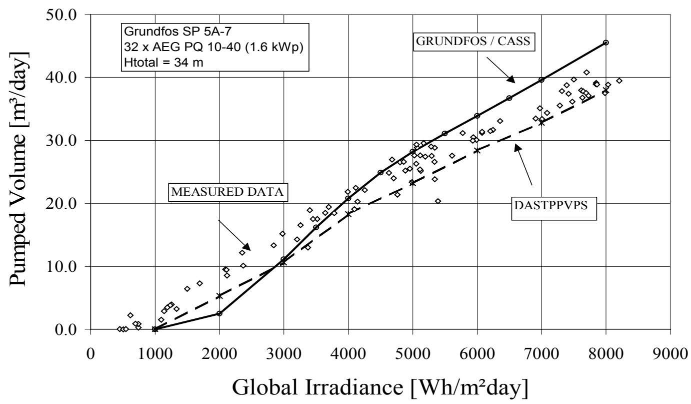
Women in particular must be intensively involved in the planning, because they are the ones who are usually responsible for maintaining hygiene and fetching water. Thus, planning should include both technical and sociological aspects.

For a quick onsite estimation of the required PVP and the corresponding costs, the following formula has been derived from measured operating data:

$$P_{SG} = 11.6 * \frac{H * V_d}{\overline{G_d}}$$

For instance, according to this formula it takes a 3.5-kWp PV generator [P_{SG}] to deliver water at the rate of 30 m³/d [V_d] at a head of 50 m [H] for a daily total global irradiation of 5 kWh/(m²/day) [G_d].

Several suppliers have developed product-specific system design diagrams in order to simplify the design process. When those graphical designs were compared with the results of the measurement programme, huge deviations have been found. These were in the order of 21 % resp. 27 % for the design diagrams of different suppliers.



Computer sizing programmes can take the daily dynamics of PVP into account and thus overcome some deficiencies of graphical sizing procedures. The available software programmes ranges from simple demonstration programs to highly flexible free-style programmes. The results of several programmes were compared with measured size data. A good agreement to the actual measured data was found with the DASTPVPS simulation and design programme developed by the German Universität der Bundeswehr in Munich. It can serve as a suitable instrument for system design and for checking the performance of PVPs.

Finally the sizing results of the suppliers have been evaluated. Under real operating conditions, most commissioned systems actually delivered considerably less water than expected.

A main reason is the average daily efficiency of about 3.0 % that PVP systems actually achieved. The suppliers were expecting an efficiency of approximately 3.5 %. If the users' consumption patterns are also accounted for in the calculations, the average daily efficiency drops to around 2.0 %. There are many reasons for the apparent loss of performance.

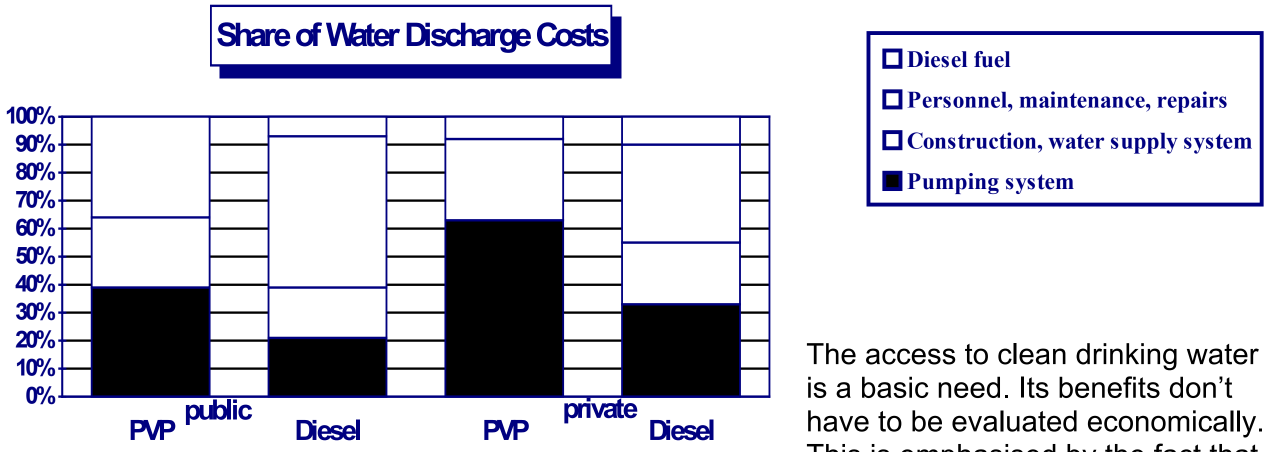
- External causes are inadequate planning data (e.g., pumping head), dirt-plugged pumps, pipes and valves, shading of the PV generator, underestimated temperature effects, premature wear of system components due to corrosive substances in the water and irregular use of water.
- System-specific causes include output limitations imposed by the inverter on an oversized PV generator, inverter and PV-generator mismatch losses, and power reduction caused by defective system components.

External causes are difficult to consider in the absence of appropriate site-specific data. System-specific causes can be avoided by careful sizing. This, however, presumes that the technical planner has access to adequately optimised system components appropriate to the prevailing climate.

Costs and Economics

Besides technical maturity and appropriate sizing procedures, the economic feasibility is of primary importance for the dissemination of PVP technology. A number of studies were conducted to clarify the conditions for an economic operation of PVP. The studies concentrated mainly on the supply of drinking water to villages without electric power. No consideration was given to sites with livestock water supply only, since these are less suitable to PVP due to their strong seasonal demand fluctuations.

As a rule, electric pumps are favourable if electricity is available and hand pumps are the least-cost option for low consumption rates and low pumping heads. However, diesel pumps are used in most villages with populations of 500 or more in unelectrified areas. Hence, diesel pumps are the main competitor of PVP.



The access to clean drinking water is a basic need. Its benefits don't have to be evaluated economically. This is emphasised by the fact that most rural drinking water supply schemes are subsidised. Consequently, the question of profitability can be reduced to the relative cost advantages between different pumping technologies.

- **Cost survey**

The findings are based on market research and cost surveys conducted in seven project countries between 1993 and 1995. Differentiation was made according to operator (public or private) and plant output. The cost survey covered the pumping systems and the water reservoirs, but not such site-specific components as wells and distribution systems that are identically for both technologies.

Comparing the initial capital outlays, the PVP systems cost between 2 and 3 times as much as the diesel pumps. Day-to-day expenditures of PVP for personnel, maintenance and repair are extremely dependent on the location and particularly on the payments for an operator, but they always remain well below those of diesel pumps.

Investment Costs of PVP [in 000's €]			
	1 kW_p	2 kW_p	4 kW_p
PVP (fob; generator, pump, inverter)	8.3	14.8	27.0
PVP (turnkey, shipment, installat. etc.)	16.9	25.9	43.0

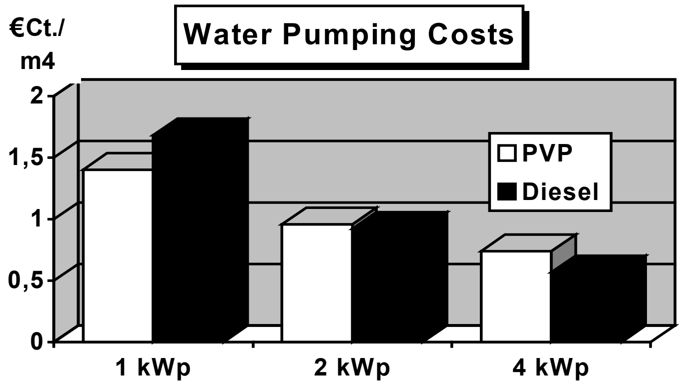
The running costs makes up for a higher proportion of water pumping costs for diesel pumps versus PVP and for public versus private owners. The higher running costs for public owners are caused by higher operating expenses. The impact of fuel costs is comparably low.

Running Costs in 7 countries [in €]		
	min	max
PVP (operation, maintenance, repair)	31	3.400
Diesel pump (operation, mainten., rep.)	920	9.800

- **Water Pumping Costs**

The specific **water pumping costs** are the main criterion for an appraisal of different pumping technologies. These are the costs caused by a pumping system, taking into account investment costs as well as operating costs, to supply one m^3 per day at a pumping head of one m. They are expressed in € per m^3.

The costs have been calculated on the basis of annuities, using a country-specific, inflation-adjusted calculatory interest rate, and taking into account the service life of the respective component. Macroeconomic factors have been ignored.



For PVP, the average costs of the 39 cases comes to about 1.5 €cents/m^3 (Example: 1 m^3/day at 20 m pumping head costs 1.5 cents/m^3 * 20 m = 30 cents/m^3). The costs decrease with increasing demand or plant size. Since this effect is stronger for diesel pumps, PVP are more favourable at smaller demands.

While this is true at all sites, the economic viability for a certain demand is strongly influenced by national, regional and sometimes sites aspects such as the interest rate or the expenses for an operator. While in one country all 6 cases investigated proved to be advantageous for PVP, in another one no competitive PVP cases could be found.

In general an economic viability for PVP can be expected if:

Technically

- High year-round utilisation of the pumped water is ensured (constant demand, no seasonal watering of cattle),
- Well-designed systems with overall efficiencies of 3 % or above and system sizes up to 2 kWp are applied (depends much on country specific conditions)

Organisationally

- Costs for operating staff are low,
- Installation, maintenance and repair work can be performed by qualified local staff,
- Additional costs for the water storage capacity can be kept low (community labour support).

Financially

- Low-interest credit lines are available,
- Import duties or other charges on PV modules, inverters and pumps are moderate or non-existent.

Investment Costs vs. Water Pumping Costs

Notwithstanding the economic advantages of PVP technology in many cases, there are still obstacles to be overcome. An important one lies in the practices and established standards of the water supply authorities.

The decision-making process of the water authorities for the purchase of a new pumping system generally takes place on the basis of bids submitted as a result of invitations to tender. The criterion for the decision is, ultimately, the cost of the initial investment. As long as only diesel pumps are included in the comparison, such a procedure may be acceptable. But this practically rules out PVP technology, because the running costs of the diesel pumps are not included in the comparison of technologies.

In many countries, financing of the investment costs lies within the responsibility of the national water authority, while the costs of operation have to be borne by the regional water authorities through provincial government budgets. This mode of cost sharing favours technical solutions with minimal investment costs instead of minimal water pumping costs. The interests of regional water authorities and users to reduce running costs and to ensure a reliable water supply is often disregarded.

Social Aspects and Acceptance

A common experience all over the world is that it is easier to install a water supply system than to ensure its sustained operation. Introducing technology into the social reality of rural communities is a task that cannot be addressed solely by technical means. It is a social task and consequently needs social preparations for the project activities. Disregard of this basic experience leads to unresponsiveness to the users' demands and to a high probability of project failure.

The participatory and educational measures of the PVP Programme aimed towards

- Building up or strengthening sustainable local community structures that can handle their own water management and the self administration of water and hygiene aspects, and
- Introducing a socially acceptable water tariff that enables the community or the operating agency to cover at least the O&M costs.

The social acceptance of PVP is not a condition for the installation at any particular site, but a result of an education-induced process that is guided by the motivation, participation and self-responsibility of the users and communities. Important indicators identified for the degree of acceptance are:

- Ownership attitudes of persons or groups toward the installations ('This is our well/PVP'),
- Regular payment of water charges by the users,
- Careful handling of technical devices and initiatives for maintenance and repair,
- Taking over obligations regarding accompanying measures (e.g. gardening, hygiene campaigns, etc.) and task assignments on a community basis.

In those project countries where the regulations and traditional water rights allowed the introduction of water tariffs, an unexpectedly high readiness on the part of the rural water users to pay for their water consumption was encountered. Precondition for the acceptance of the water tariffs by the consumers and their continued readiness to pay are sensible community participation measures and the experienced reliability of the PVP technology.

When the users are charged according to their consumption, the water demand will at least be cut in half as against monthly flat rates. Such causal relations between tariff system and consumption should be taken into consideration by the planner, because proper matching of the PVP to consumption habits affects specific water costs and, in return, the affordability of the water for the users.

Perspectives

The tremendous unsatisfied need for clean drinking water in rural areas of developing countries will surely continue for many years to come. Since the electrification of remote rural areas will not be affordable in the foreseeable future, the demand for stand-alone pumping systems will endure.

With an availability of 99 % PVP systems have proven their technical maturity and reliability. Tandem plants promise future improvements in energy utilization.

Cost analyses show that PVPs with ratings up to about 4 kWp are cost-competitive vis-à-vis conventional diesel pumps. The smaller the demand and correspondingly the pump, the more attractive the photovoltaic option will be, though prices do vary from region to region. These cost advantages are augmented by such non-monetary aspects as reliability, ecological viability and the ability to pump water at inaccessible locations without need of fuel. On the other hand diesel pumps are more flexible being adapted to changing demand patterns.

Even though the economic feasibility and other advantages of PVP have been demonstrated, the relatively high initial investment costs and foreign-currency outlays often preclude their dissemination. In such cases, development banks should provide compensation in the form of easy-term loans or other financing models.

Suppliers should take advantage of the good preconditions for a wider PVP dissemination. This requires a stronger engagement in developing countries in terms of product representation, consultancy services for water utilities, and building up of a sales and maintenance structure incorporating local partner enterprises. The commercial diffusion of PVP will be contingent upon an in-place maintenance structure and the local availability of spare parts.

Despite all obstacles encountered in the past and the complexity of an intended dissemination process, the accumulated international know-how allows the integration of PVP as a well-defined option for large-scale water supply projects and strategies. The satisfaction of the basic need for drinking water supply will provide a sustainable market for PVP.

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2.4 Global Environment Facility (GEF)/World Bank Assisted China Renewable Energy Development Project PV Component

Case study prepared by Z. Li, IT Power, UK

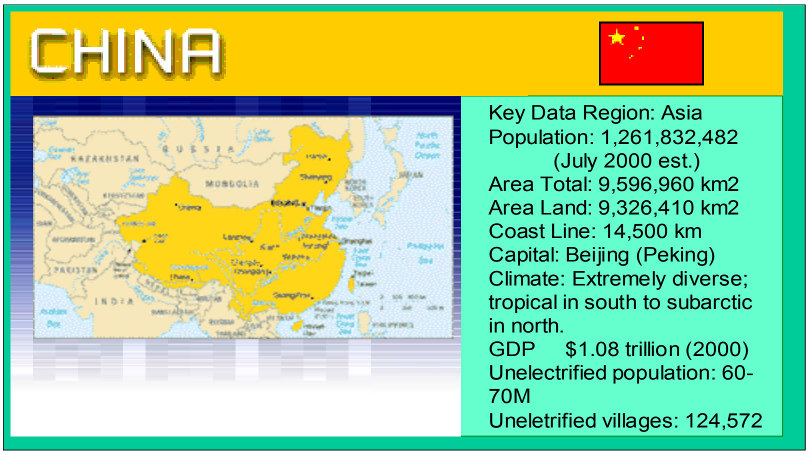
Introduction

General Information

China is the largest developing country in the world with a total population of 1.2 billion. According to China National Statistics, the GDP per capita was about USD 800 in 2000 and the average annual economic growth rate has been 6.5% over the last 10 years. Although the unelectrified portion is quite small in China compared to the total population, the absolute number is very large. Today there are still 70 million people in China without access to electricity service and most of them live in remote areas that are not economically viable for grid extension.

The energy structure in China relies heavily on coal, which provides more than 70% of the total energy supply. The domination of coal is one of the major causes of urban air pollution and the deteriorating ecological environment. The Government of China has adopted a wide range of policies to re-structure its energy structure and encourage the use of renewable energy. Renewable energy is a vital component of China's long-term energy strategy for rural development. China has strongly supported small hydropower (<25 MW), biogas, small wind turbines and Solar Home Systems (SHS) over the past 35 years, to provide energy and electricity to isolated rural populations.

Project Background



In 1995, the Government of China (GOC) declared a new commitment to renewable energy development, as outlined in the New and Renewable Energy Development Program, 1996-2010. This programme aims to improve the efficiency of renewable energy technology applications, lowering production costs and enlarging the contribution of renewable energy to overall energy supply. The 1995 Electricity Law also extends GOC's support to solar, wind, geothermal and biomass energy for electrical power. Recognising the need for a strategic orientation to renewable energy development, the GOC, with the assistance of the World Bank and GEF, has undertaken sectorial analyses, which have culminated in a strategy document and two detailed sector studies.

The project design is based on these studies, which conclude that China requires a market-driven approach to renewable energy development. Following the recommendations of the above sector studies, the China Renewable Energy Development Project would support the development of the two most promising renewable energy technologies, grid-connected windfarms and solar photovoltaics (PV) for rural applications.

Aims and Objectives

The project aims to use state-of-the-art and cost-effective wind and PV technologies to provide modern energy services to dispersed rural households and institutions in an environmentally sustainable way. The PV component is to supply about 10 MW of PV systems to households and institutions in remote areas of six North-western provinces to stimulate the commercial SHS market in western China.

Project Description

Project Plan

The *Solar Photovoltaic (PV) Component* is designed to provide a direct grant to PV system companies to assist them to market, sell, and maintain 10 MWp of PV systems, an estimated 300-400 000 systems, in western China. The companies will receive a GEF grant of USD1.50 per Wp of PV capacity, per system with a capacity of 10 Wp or greater.

Project Financing Plan

The total budget of the Solar PV component is about 80 million USD. This is broken down as follows, 20 million USD as the grant from GEF and 2 million USD from National and Local government agencies with the remainder from the rural households and institutions that buy the SHSs from the qualified project companies.

A total of 15 million USD will be used to provide direct subsidy to the companies at USD1.50 per Wp of PV capacity per system. The remaining 5 million GEF grant will be used for the Marketing Development Component to support the companies to assist PV market development. The 2 million USD coming from the Local and National Government is for the project management office staff and for providing part of the office facility. The rest of the financing is from the SHS end-users that actually buy the system on the market.

Source	Amount (million USD)	
GEF	15	Subsidy to SHSs
GEF	5	Market development
Local and National Government	2	PMO staff, Co-ordination and Office Facility
End-users	58	Buy SHSs in market
Total	80	

Project Infrastructure and Institutional Issues

- **Project Oversight and Policy Guidance**

A project-leading group provides overall policy guidance. This group is chaired by a Vice Minister of SETC, and includes representatives of the related Ministries including:

1) The Resource Conservation and Comprehensive Utilisation Department of State Economic & Trade Commission (SETC)
2) The Departments of Infrastructure and Foreign Capital Utilisation of the State Development and Planning Commission (SDPC)
3) The Ministry of Finance (MOF)
4) The Hydropower and New Energy Development Department of State Power Corporation (SP)
5) The Department of Industries of the Ministry of Science and Technology (MOST)
6) The Department of Environment and Energy, Ministry of Agriculture (MOA);
7) The State Environmental Protection Administration (SEPA)

There are also similar project-leading groups at provincial level in most provinces participating in the project.

- **Project Co-ordination**

A Project Management Office (PMO) is responsible for overall project co-ordination, assisted by other agencies at the central and provincial level. The PMO is chaired by the Chief of the Renewable Energy Division of SETC and assisted by a technical support group of domestic and international consultants. The Project Implementation Unit (PIU) was also created under the Provincial Economic & Trade Commissions (ETC's), in provinces participating in the PV Component, to facilitate the ability of the PMO to co-ordinate activities at the provincial level.

- **Project Implementation**

Commercial PV companies should undertake the sales of PV systems to rural consumers. These companies are made up of private companies, joint ventures and companies wholly or partially owned by research institutes or state-owned enterprises. The companies should directly sign the sales contracts with the customers by providing the systems or components, assembly, system installation and maintenance. Companies would receive a direct grant of $1.50 per Wp of PV, for each system sold and installed with a capacity equal to or greater than 10 Wp (each eligible PV stand-alone or PV-wind hybrid system could have a PV capacity of 10 to 500 Wp).

Capacity Building

There are a series of capacity building activities that have been undertaken at the project preparation stage prior to project implementation in order to strengthen institutional capabilities for PV quality assurance, project management and public awareness and to increase the commercial capabilities of the PV companies.

The Capacity Building activities include:

- Capacity building for product quality assurance including establishing national PV testing and certification centres; establishing national PV component and system standards; and improving quality control procedures of PV equipment suppliers;
- A public information campaign including publishing the system brochure, providing lectures on SHSs operation and a commercial radio programme to give consumers objective information about PV systems;
- Providing business training workshops and business consultant service to increase the commercial capabilities of the PV companies.
- Providing training workshops and a study tour to PMO staff and government officials on project implementation and management, including project monitoring and evaluation.

Quality Assurance

- **Qualification of the commercial PV companies**

To be selected to participate in the project, a company must demonstrate that it would: (i) offer a comprehensive consumer protection package, including warranties and adequate after-sales service; (ii) use certified equipment and components; (iii) agree to abide by a company conduct code for good customer service; (iv) agree to establish an escrow account, based on the GEF direct grant due to the company, to be used to assist customers with serious unresolved complaints against the company; and (v) provide the operational and financial information required by the PMO for project monitoring and evaluation. Seventeen companies have been pre-selected to receive assistance to help them prepare business plans and participate in the project as commercial PV companies.

- **Technical Standard and Monitoring to PV System**

The national test and certification centres and national PV component and system standards have been established under the project. The PMO encourages qualified solar PV component suppliers in China and around the world to be involved in the project through the supply of components and systems, e.g. solar module, inverter, controller, battery, lights, etc.

For quality assurance, the PMO requires the interested suppliers to provide the following evidence to be able to be involved in the Project:

- Product description and specifications,
- Supplier contact information and
- Either a certificate by an internationally recognized testing institute (institutes with ISO 25 certification are acceptable) or from a testing organization in China acceptable to the PMO, to prove that their products meet the technical specifications of the project. There are several testing centres in China designated by the PMO to conduct testing according to the project specifications and issue certifications.

The PMO will maintain and publish a list of qualified component suppliers and their certified product descriptions as guidance to participating PV companies. This list is available to the participating PV companies and dealers by mail, and the list is published on the project web site (http://setc-gef.newenergy.org.cn) in both Chinese and English.

The PMO is also offering limited assistance to interested China-based PV suppliers to assist them to improve the quality and performance of their PV products so that their products could meet the requisite standards. The Hefei University of Technology has been contracted to provide such design assistance services.

The information package is available to all suppliers on request, which includes the following documents:

- Project description
- Technical specifications for PV systems and components
- Testing & Certification Procedures for Module, Controller, DC/AC Inverter, and DC lights
- PV Components Testing & Certification
- Instructions for applying for testing and certification assistance
- Testing and certification Application Form
- Design Assistance Services from Hefei University of Technology
- Instructions for applying for design assistance services
- Design Assistance Services Application Form

Project Impact

Whilst the actual project implementation has been postponed, preparation activities in capacity building and quality assurance have already had an impact on SHS quality and market in the project region.

Quality Assurance

The technical specifications on module, controller, DC/AC inverter and DC lights are called ‘the World Bank Standard’ by the PV companies. PV companies complying with this standard see it as a major advantage when competing against other companies in the SHS market in western China. Before the project, there was no regulated and comprehensive standard for SHSs in the market. As the public lacked awareness of SHS quality, the market competition mainly went for price competition. As a result, quality had been neglected and unreliable PV systems were destroying the consumer market. The system standard and test procedure has greatly improved the systems' quality and it is essential to create a long term and sustainable SHS market.

Capacity Building

The other major impact of the project so far is that the commercial capabilities of the PV companies have significantly improved. Most of the PV companies are small scale companies and lack commercial capabilities, which made it very difficult for the companies to obtain loans from commercial banks and most of them lack of skills for business plan development. The project has offered tailored business training workshops to all the companies and provided individual business tutor services including financing, accounting and business development plans to the companies that are facing the specific problems. As a result, some companies have been offered bank loans from local commercial banks, and quite a few companies are seeing their SHS business grow every year even before the companies have benefited from the direct GEF subsidy on sales.

The expected impact of the project in the long term is to enlarge the SHS commercial market and create a sustainable SHS market in western China.

Lessons Learned and Success Factors

Success Factors

Capacity Building ---The capacity building activities for the different levels of project participants at the project preparation stage will be essential to the successful implementation of project.

Quality Assurance – Establishing the national test and certification centre and issuing the national component and system standards are a vital output of the project, and it is a crucial instrument to regulate the SHSs market in the long term.

Lessons learned

Direct Subsidy – Direct subsidy to the PV companies can stimulate the SHS market, however, it also has had a negative influence on the market where it has already been commercially operated, such as Xining, Qinghai province.

Institutional Issues – Project implementation has been postponed for several years due to the national institutional co-ordination issues, which is having a devastating effect on the PV companies participating in the project.

2.5 JICA PV Project - Case of Zimbabwe

Case study prepared by Takayuki Tani, IEEJ, JPN

Introduction

General Information

According to a survey conducted in 1992, Zimbabwe has a population of 10.4 million and a total number of households of 2.16 million, 70% of which live in rural areas. In 1994, the gross domestic product (GDP) amounted to ZWD 76.2 billion, and GDP per capita was ZWD 7,200 (approx. USD 850). Major domestic industries are manufacturing (mining), agriculture and tourism. Principal export items are mineral products, such as gold and nickel, and farm products such as tobacco and cotton. Zimbabwe is almost self-supporting in food.

The latest survey (1997) conducted by JICA showed that the average annual income of general households was ZWD 36 000(USD3 000) nationwide, and around ZWD 26 000 (USD 2 200) among the unelectrified households.

Agriculture industry consists of the commercial plantations run by large-scale farms, the national-developed communal plantations, and the resettlement plantations. Compared with the commercial plantations, the common and resettlement plantations are lower in productivity, which results in lower incomes for the farming families there.

Electricity Supply and Rural Electrification in Zimbabwe

In Zimbabwe, electricity is supplied by coal-fired power plants (fueled by ample coal found in the country), hydropower generation is primarily from the 1958-built Kariba dam, and purchased power is from the grid interconnection with neighbouring countries. The total installed capacity amounts to about 2 000MW. The total power supply was about 10 000 GWh supplied in FY 1995, roughly 30% was covered by purchased power from abroad.

On the demand side, the biggest consumers are industry and commerce. Households account for about 20%. Per capita electricity consumption is 2.5 kWh / day, which is about 1/15th of the world's average.

In Zimbabwe, about 30% of households are electrified. The household electrification rate exceeds 70% in urban areas, but remains below 5% in rural areas. By province, the electrification rate is 25% at highest and 10% at lowest.

In its effort to promote rural electrification, the government initiated a ten-year programme in 1997, under which local economic centres, including DSCs (District Service Centres) and RSCs (Rural Service Centres), are electrified by existing grids extension. No special electrification programmes are planned for households.

Aim and Objective

This study is designed to help to prepare a photovoltaic (PV) - based rural electrification project, in which even the low-income class can participate.

Project Background

Zimbabwe is rich in solar energy resource, supplied with solar energy equivalent to about 2 000 kWh/m^2 a year. In 1993, partially financed by UNDP, the GEF (Global Environmental Facility) project started, under which a total of 9 000 household-type PV systems of 45W-PV module type were to be installed in five years. In addition, in 1996, Harare hosted the WSS (World Solar Summit 1996), where the "Harare declaration on sustainable development of solar energy" was adopted. Since then, Zimbabwe, the country chairing the Summit, prepared a decade-long solar energy utilisation programme, or Zimbabwe Solar Program 1996-2005, and called for financial co-operation. On top of household-type PV systems, this programme also included PV water pumping, public facility-use systems, mini-grid PV systems, etc.

Zimbabwe has about 50 firms specialised in the supply of PV-related equipment and system installation. They are engaged in activities such as the manufacture, import and sale of PV-system components and equipment and their installation. The majority of these firms are of small to medium size with less than 20 employees and annual sales below USD10 000.

Along with the implementation of the GEF project, these firms established SEIAZ (Solar Energy Industries Association of Zimbabwe), which is active in information exchanges and promotional efforts.

Project Description

Project Design

The intended results of the GEF project are to prepare a rural electrification programme, which allows the participation of the households with lower incomes. Through the installation and management of the monitoring systems, problems related to both the management and the technical processes were found. Solutions to these problems were considered and transferred to the prepared rural electrification programme. At the same time, in order to estimate the demand, select supporting measures and evaluate the economics, specific surveys were conducted to assess the social-economic conditions, loan systems and economic conditions of the villages.

To identify and analyse the problems arising in the implementation of the GEF project from various sources in the preliminary study, a pilot project was prepared with the aim of eliminating such problems.

With the co-operation of the local counterpart and local administrative organisations in Zimbabwe, the pilot project site was selected. The site was about 150 km from the capital Harare and the two groups with 50 households each were 50 km away from each other.

The fee per PV system was fixed according to the results of the village social-economic survey and the GEF project. The initial payment was 750 ZWD and monthly payment was 75 ZWD. (12 ZWD/USD)

An operator of the pilot project was selected from NGOs that had experience with PV-system installation / management. The operator was requested to collect management-relevant data, such as the rate of collection of fees. By analysing its operation and management results, the results will be used in the preparation of a full-scale rural electrification project.

To determine whether a "system sales" or an "electricity supply" service (or ESCO (Energy Service Company) is more practical for PV system-based rural electrification, the two approaches were compared. Also, the qualifications for an ESCO were considered in comparison with ESCO-candidate organisations in Zimbabwe.

Technical Design

A 25Wp system was designed for the household of pilot project. The basic system components are as follows:

- PV panel — 25Wp mono-crystalline
- Battery — 12V 40Ah deep cycle or 60Ah automobile type
- Charge controller — 10A
- Lamps — Two 7W fluorescent lamps
- Voltage dropper — 6 and 9V for radio or radio cassette
- Panel support pole

Locally available PV-system components were assessed and some were selected for the 25Wp system after design modification and trial manufacturing as necessary. In the process of product quality inspection and trial manufacturing, product quality problems were pointed out and methods to improve manufacturing technologies were proposed. Also, by checking the system installation work, improvements to the installation method were proposed.

The operation and maintenance conditions were analysed from the data logger records and local technician's maintenance records, so that the user operation of the systems could be used in the preparation of designs for the full-scale rural electrification project.

Survey on Farming Village Societies

The potential demand for PV systems was estimated by surveying electricity needs and economic conditions in Zimbabwe's rural areas. A survey was also conducted among households currently equipped with PV systems and existing problems were learnt.

In total 200 unelectrified households and 200 households equipped with PV systems, as well as 50 unelectrified public facilities and 50 public facilities equipped with PV systems were surveyed. Since the full scale PV-based electrification project was to be nationwide, the questionnaire had to cover a number of provinces. Provincial characteristics, such as average income, population density, electricity needs, were also examined.

Evaluation of GEF project

The GEF project set up a scheme to facilitate potential users to buy PV systems by the use of a revolving fund which allows purchase by 2 – 3 instalments per year at 15% interest, compared with the high market rate in Zimbabwe of 35-40%. A managing organisation of the project (PMU) was created. PV-system parts imported by the PMU were exempted from import tariffs so that the system installation cost could be lowered. System installation was left to private firms, while maintenance was done either by the installation firms or the users by themselves. The system installation cost was paid by AFC to the installation firms to be later reimbursed by the users in instalments.

Description of the JICA Project

The Scheme of the JICA Project

The JICA project was designed taking into consideration the results from the GEF project and the situation in Zimbabwe. Its main characteristics are as follows:

- The JICA project was designed to develop a scheme in which lower income groups can participate.
- PV-system components were procured from domestically-manufactured products as far as possible. To that end, a controller applicable to a very small-capacity PV system (25W) was developed and technology transfer was carried out to enable local manufacture of the controller.
- A managing organisation which can ensure a continuity of service was established. The organisation is responsible for the maintenance and management of the installed PV systems so as to guarantee the sustainable use of the systems in the long run.
- Local engineers were assigned to the managing organisation. They are responsible for PV-system maintenance.
- A training facility for local engineers and system installation workers is to be established to upgrade their technical expertise in PV system maintenance and installation.

Implementation of the Project and its Evaluation

- **Evaluation in Management Terms**

An electricity supply service approach was employed, which allowed the users to pay the charge for electricity use, instead of buying a PV system. This made then scheme more accessible to lower income groups.

The evaluation of PV-system components is detailed later in the section "evaluation in technical terms." Overall, domestically manufactured components had quality problems.

An NGO was given the contract to act as the managing organisation with responsibility for the management and maintenance of the pilot project, as well as the collection of charges. Initial problems were caused by the fact that users consumed more electricity than was originally expected, suppliers were late in their deliveries and because of the poor-quality of the PV system components. It therefore took more time than expected time before the management was running smoothly. The NGO was found to be poor at disciplining users for illegal use and non-payment of fees. Amongst other factors, the distance between the NGO office and the service areas had a negative effect on efficient management.

Local technicians to be responsible for the maintenance work were selected from several local candidates in the service areas after receiving training at a JICA-sponsored training course. It was estimated that a local technician, once experienced, could cover more than 100 households per month.

Users earning regular salaries were charged every month, but it was confirmed that farming families would be better served if charged once a year during the harvest time.

The pilot project was transferred from JICA to the Department of Energy of Zimbabwe once the JICA study was completed and management of the systems remains with same NGO. The systems are working well and all batteries are used without replacement for three years. The greatest management problem is the weakness of the Zimbabwe dollar which means that the collected fee is not sufficient to replace all the batteries with the same standard of quality.

- **Evaluation in Technical Terms**

PV-system components:

- The same imported PV modules as in the GEF project were employed, and they produced no particular problems.
- Domestically manufactured batteries were used. Many problems including the early failure of a number of batteries, were caused by users consuming more electricity than originally expected and because of inappropriate setting of the charge controllers,
- While domestically manufactured controllers were used during the initial stage, the charge controllers were replaced with improved ones that consumed less power. These were later replaced with a further improved model, not available locally. The parts for the improved model were procured and assembled in Japan.
- Of the fluorescent lamps actually installed, about 1% failed and had to be replaced with new ones.

System installation work:

- The workers were rough in installing the system. Without having appropriate tools, they often damaged the wall and roof while installing the systems. They were instructed to use appropriate tools and work more carefully but in most cases no change in performance was seen.
- Neither the azimuth nor the tilt angle of PV modules were set correctly. The workers did not have the necessary instruments and tools for accurate setting and some did not understand the concept of angle and azimuth..
- Some of the wiring work was so poor the PV system was connected to the battery simply by winding the wire around the terminal.

Data logger-based evaluation of operating conditions

- The irradiation data used in designing the systems was collected by the Harare meteorological observatory. It was confirmed that this data was little different to that actually measured in the pilot project districts.

- The locally-manufactured charge controller first installed was found to have its HVR (high voltage reconnection) set at 12.5V despite the specification of 13.5V. This caused difficulties in recharging, and made the recovery of the battery slow. The improved model demonstrated operating characteristics exactly as expected.
- Operating conditions of the systems installed in households showed that, due to greater electricity consumption than expected, the systems were running at full capacity. While the systems were designed with some allowance for the amount of sunshine, etc., electricity supply was sometimes interrupted when non-sunshine days continued so long that the battery charge was depleted. The greater electricity consumption is attributable to the fact that many households used not only lighting, but TVs as well.
- Users' evaluation results showed that the number of the users were satisfied increased from 44 in December 1997 to 84 in April 1998. The outcome suggests that the system use is entering the stable stage with a falling number of initial problems. Most problems were related to the charge controller and battery.
- In the process of monitoring, it was found that the users consumed more electricity than expected and that many users hoped to increase the capacity of their systems. Accordingly, by designing a larger 50W system and confirming that capacity expansion could be made with a minimum additional investment, this was done upon the users' request.

Quality of PV in Zimbabwe

Charge Controller

The controllers from one company were each opened and checked for quality control. Inside controller boxes were found dead insects, loose nuts and almost all had plastic shavings from the drilling of mounting holes.

The relays used in the controllers do not have covered contacts so foreign materials could easily get between the contacts and cause the controller to fail. Some printed circuit boards were found to be missing a support nut.

Instead of using spacers to hold the boards above the box, a nut was placed above and below the board and it was common to find the board twisted as a result of the bottom nuts being at different levels. Also, instead of placing a proper spacer between the cover and the plastic box, a large nut was used.

The electronics assembly seemed reasonably well done although transistors were mounted with excessively long leads which could be easily bent into a shorted condition. No conformal coating was applied.

Printed circuit traces carrying power were adequate for the low currents in our 25 Wp systems but could not carry the 20A that was claimed by the company technicians without excessive heating and voltage drop.

Since several controllers did not work properly after installation, despite provision of "QC" documentation by the company, there were probably problems in the inspection process as well.

Assembly of Charge Controller

Since charge controllers available in the local market generally have high internal power consumption (thus requiring changes in the circuit design to reduce power consumption, alterations in composition of parts, and the addition of a contact maintaining circuit to prolong relay contact), procurement of other local parts for further alterations was deemed impractical. It was then decided that prototypes and other parts were procured in Japan and brought to the study area for assembly and subsequent monitoring.

The results are:

1. Company A

This company only soldered the components to the printed circuit boards and delivered them in semi-completed form. They were therefore instructed to adjust the operating voltage settings with our counter parts, to complete them.

On investigation of the workshop of this company, it was found that an outside contractor was assembling and adjusting charge controllers. The workshop lacked an adequate DC power supply and instruments to perform the adjustment of charge controllers. They were only capable of assembling printed circuit boards.

2. Company B

This company delivered charge controllers in fully completed form.

The production process consisted of separate work lines so it was able to produce good quality products comparable to those manufactured in advanced countries. Also, the final adjustment process area was fully equipped with all of the necessary measuring equipment, and the workers were well trained. The final products were therefore of good quality.

3. Company C

Unlike the previous two companies, which were co-operating with foreign enterprises, this company was managed and staffed entirely by Zimbabweans. It was supported by the GEF project.

After the re-consignment arrangement was agreed to, this company delivered complete products in only four days, which was faster than either of the other two companies.

The results of the performance evaluation were good, and it was clear that this company was doing its best to co-operate with the GEF. Though the company was small, they are one of the key companies in PV technology in Zimbabwe. This factory would be a good choice for a future re-consignment arrangement.

Quality control systems in Zimbabwe

1. A set of standards for stand-alone home systems was developed and drafted for examination during our study such as;
   - Photovoltaic Modules
   - Charge Controllers
   - Batteries
   - Fluorescent Lights
2. System Design and Installation.

(1) Standard Association of Zimbabwe (SAZ)

The principal functions of SAZ are to prepare, publish Zimbabwe standards and to promote their adoption.

(2) The Solar Test Laboratory

The PV laboratory for the GEF project was established to assess the quality of the equipment and components that would be imported for the solar companies. In 1997 two staff members of the project were seconded to the Danish Technical Institute for the training of solar lab testing and during the JICA study, Japanese experts trained them and transfer testing technologies.

(3) Training for installation and maintenance

GEF held several workshops for training of installation and maintenance for NGO and new companies.

JICA study team also provided a training class at one of technical collages of Zimbabwe to foster trainees and train local technicians.

2.6 Lessons from the Regional Solar Programme (RSP) in the Sahelian countries

Case study prepared by A Shanker, IED, FRA

Introduction

Between 1991 and 1997, the RSP installed 626 Solar Photovoltaic pumping systems and 644 Community Systems (refrigerators in Dispensaries, lighting systems in rural health centres and in schools) in the 9 countries of the CILSS (Comité Inter-Etat de Lutte contre la Sécheresse au Sahel). These countries are Burkina Faso, Cap Verde, Chad, Gambia, Guinea Bissau, Mali, Mauritania, Niger and Senegal. The programme was financed by the European Commission.

This document highlights some of the key features of the programme and interested readers are invited to refer to the detailed publication on the lessons learnt published by the European Commission.

Project Aim and Objective

The Regional Solar Programme aims to contribute to proving the willingness and capability of villagers to pay for a reliable water supply service.

Project Description

Project Design

- Payment for Water

While in the 80's water was considered as a gift of God and therefore considered to be free, today, payment for water is considered normal. When they are well informed, villagers agree on the idea that the price of water should be sufficient to cover operation, maintenance (of the full system including hydraulic component which covers water tank and water distribution system) and renewal costs (excluding civil works which has a life time of 50 years at least). This has been possible only through strong involvement of the end-users and through building of a sense of ownership, materialised, amongst other ways, through a compulsory down payment before starting construction.

Villagers are organised in a village water committee, which takes on end-user responsibilities as a community, including daily caretaking, collections and management of water payments that are dispatched to different accounts – deposit account for daily expenses and a term account for renewal. In most countries, price of water is around 250 XOF/m^3 (0.38 EURs/m^3), and can reach the double in certain conditions.

Items	Amount (XOF/m^3)	Example
"Total guarantee contract" including full guarantee, maintenance, replacement of inverters and pumps	60 to 80	In Niger, the total guarantee contract between the village level end-users associations and the service company was extended through direct negotiation between parties for an additional period of 10 years after project termination, at an average of 83 XOF/m^3.
Renewal of PV modules	30 to 60	On the basis of 6 EUR/Wp (public price of PV modules in the CILSS countries) depreciation over 20 years

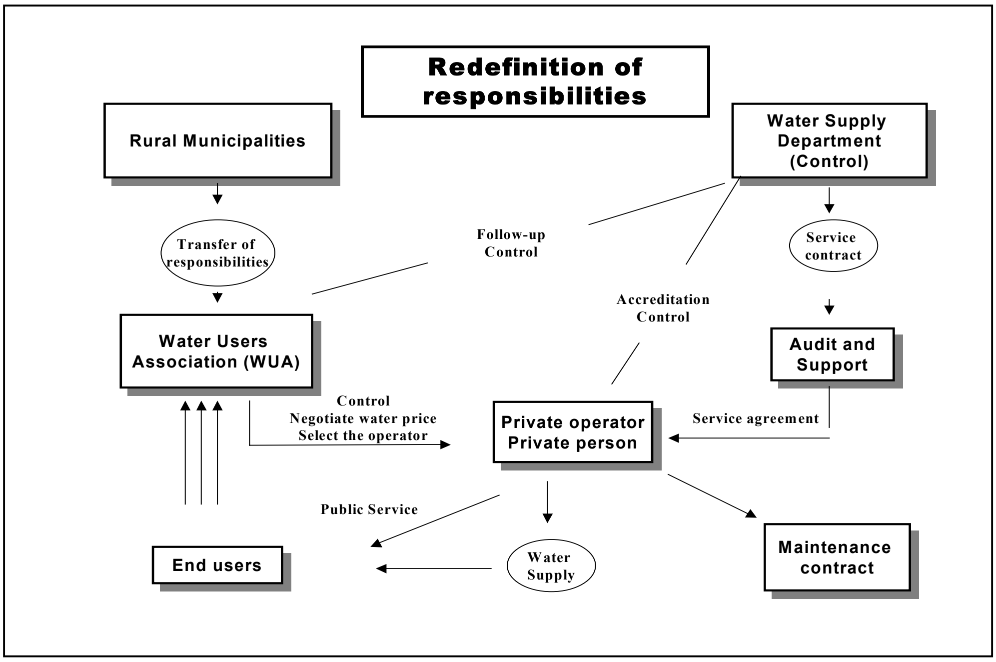
Items	Amount (XOF/m³)	Example
Operation and daily maintenance	50 to 90	In Niger : payments to village associations for daily O&M represents one third of collections. In Mali, the local private operator is usually paid 80 XOF/m³.
Audit + Follow-up and Evaluation	20 to 30	In Mali, independent local private consulting firms are responsible for these activities and are paid an equivalent of 20 XOF/ m³.
Miscellaneous	20 to 50	Water network extension, individual connections, losses,… etc

Collection of payments averages around 70%, which is quite a remarkable performance for what is a rural development project in remote areas. An in depth analysis has shown that recovery levels vary widely not only between countries but also from village to village: it depends on the efficiency of the local based management organisation, rather than on the capability to pay of the villagers.

Seasonal variations as well as changes in demand / consumption patterns over time have been observed: average capability and willingness to pay for water varies from an average of 3 - 5 litres / day / person to 8 – 10 litres, with large discrepancies between the dry and wet season, which proves that villagers are still using alternative sources of water. Over time, once they are confident with the reliability of PV water supply, villagers demand shifts towards improved service quality, from village community taps to individual household connections.

Project Infrastructure and Institutional Issues

Most countries have embarked in the establishment of a new institutional framework, based on a transfer of responsibility from the Centre to local bodies, elected or not. The RSP has contributed to develop a scheme of decentralisation of responsibilities at the village level. It has also shown the limits of voluntary management and maintenance by the Community, when systems become more sophisticated. Professional and very locally based private operators must play a key role. This has to be accompanied by support to village associations, particularly in the formulation and audit of any agreement between the village and a third party. This implies the emergence of



independent bodies in charge of this follow-up, which need to be financed and to have the required competence level.

Capacity Building and Quality Assurance

- **Technical Capability**

The RSP has laid particular emphasis on support to the development of local know-how through built-in training programmes and by adopting an integrated quality control approach, covering system design, specifications, and measure of performance in laboratories. On site, this component covers training of local installers, measure of performance 5 years after installation. The cost of this quality control approach is very low compared to the systems cost but represents nonetheless significant amounts which need to be clearly earmarked:

a) Definition of the Quality Control Approach : 0.14 EUR / Wp (0.72 % of systems cost)

b) Laboratory test for the Quality Control Approach: 0.25 EUR / Wp (1.3 % of systems cost)By adopting this quality approach, the RSP has contributed to prove the high reliability of the PV technologies: 5 to 10 years after installation, more than 95 % of systems are still providing water; mean time between failure averages at 6 years.

- **Capability to Maintain Systems**

During the programme, small PV dealers have signed full guarantee maintenance contract. In some countries, contracts have been extended for 5 or 10 additional years. Today, recovery levels of these maintenance contracts are still high, but decreasing. The behavioural interpretation for this phenomenon is that these deposited funds do not need to be used before long periods (minimum of five years) in the eyes of the villagers, and therefore, the villagers do not perceive the importance of continuing to contribute.

Country	Currency	Maintenance contract		Level of payment of maintenance contracts
		Amount due	Amount paid	
Burkina Faso	XOF	42 320 000	37 830 000	89 %
Mauritania	MRO	13 270 000	9 440 000	71 %
Niger	XOF	50 373 770	48 744 135	97 %
Gambia	GMD	1 549 600	1 160 800	75 %
Chad	XOF	59 572 500	53 033 000	89 %

- **Involvement in Systems Management**

In some countries like Mauritania, the Central Public Authority together with the village level association has delegated to a village based private entrepreneur the management of the system management. This local level private operator is solely responsible for the correct functioning of the systems. For his remuneration, he retains the remaining cash after payment towards the various accounts: maintenance contract, renewal, etc. Typically in each village, 5 to 10 permanent jobs are thus created.

Project Impact

By its size, the RSP has contributed to change the perception of the role of the Solar Photovoltaics for village water supply in the Sahelian countries. For large villages (1500 to 3000 inhabitants), it has proven to be the reference option, making the diesel option the alternative one.

2.7 Need, Policy, Market Development: PV-Dissemination in Namibia

Case study prepared by H. Muller and R. Posorski, GTZ, DEU

Introduction

General Information

Namibia has a land area of 824 269 km^2 and is located on the South West Coast of Africa. The population in 1999 was estimated to be 1.8 to 2 million with an annual growth rate of 2.7 %. The labour force was estimated at 1 000 000, of which 50 % was engaged in rural agriculture, although it was estimated that 37 % of the population lived in urban areas. The literacy rate was estimated at 38%.

The Gross Domestic Product was estimated at 3,230 million $US in 1996, with a growth rate of 4.1 % between 1990 and 1996 (and 2.5% from 1996 to 1999). The economy was heavily dependent on the extraction and processing of minerals for export and mining accounted for almost 25 % of GDP. Average annual inflation over the period of 1990 to 1996 was estimated 11.2 %. Half of the population depended on agriculture for its livelihood with 85 % of the agricultural income being provided by beef production. Namibia was also one of the main fish exporters in Africa. Exports in 1996 were estimated at $US1, 450 million and imports were estimated to be 1,550 million $US.

However, the economic growth is focused on the urban, industrial sector, whereas the living conditions in remote, rural areas remained virtually unchanged. Therefore, one of the highest ranking priorities of the first National Development Plan (NDP) of Namibia is the socio-economic development of the rural population by providing / improving their access to public services and infrastructure such as health care facilities, education, transport, water and energy.

The Namibian energy sector is suffering from three major problems, which are common to most developing countries in Africa:

- The high dependency on imported fuels and electricity (all fossil fuels and the bulk of electricity is imported)
- The large disparity in access to adequate energy supply between **urban** and **rural** population (only about 6% of rural households are connected to the public electricity grid)
- The dwindling forest resources rendering the supply of firewood increasingly difficult and expensive (about 70% of the rural population still depend on firewood as major cooking fuel)

In 1999, the overall installed electrical capacity was about 384 MW, with an annual production between 994 GWh (1994) and 1255 GWh (1998), depending on the available water flow at the 240 MW Ruacana hydro power station, which provided between 45 % and 60 % of Namibia's electricity. Shortfalls in supply are met by imports from South Africa.

The Namibian Energy Policy

As stipulated in the White Paper on Energy Policy in Namibia from 1998, the national energy policy is aiming at:

- Effective governance
- Security of supply
- Social development
- Investment and growth
- Economic competitiveness and efficiency and
- Sustainability.

In line with these objectives, the government undertook considerable efforts to improve the living conditions in rural areas in order to narrow the gap in development between urban and rural settlements by extending the public grid as far as possible. After independence, the Namibian Government embarked on an ambitious rural electrification programme, implemented by the state owned utility NamPower under the responsibility of the Ministry of Mines and Energy. Rural electrification is considered as one measure to improve socio-economic living conditions of the rural population. The reduction of in-door pollution and related health risks, deforestation and desertification are desired side effects of the programme. Traditional energy sources of the non-electrified rural households are fuel wood, kerosene, candles and paraffin. Dry cells are commonly used for radio/cassette players and torches.

However, due to limitations of government budgets and the large distances to be covered, only between 8 to 15% of the rural households, depending on the region, could be connected so far. In ex-post analyses it became obvious that the specific electricity consumption per capita in newly electrified villages remains rather low, covering only the basic needs for lighting, radio and TV and, to a very limited extend, for cooling and other domestic applications. This low specific demand and the dispersed structure of settlements are the limiting factors for the economic viability of rural electrification programmes based on grid extension.

In 1992, SADC/TAU had carried out an "Assessment of Applications and Markets for the Solar Photovoltaic Systems in the SADC Region", which identified a lack of inter-regional co-operation, affordable financial mechanisms and reliability as the primary barriers to the dissemination of photovoltaic systems in the SADC area. Suggestions to alleviate these barriers included the development of a code of practice to cover system performance, the development of an industry co-operative body to provide training and information concerning the design and installation of systems, and the removal of prejudicial tariffs which were viewed as providing an advantage to traditional generating systems. The provision of affordable financing mechanisms remained the most problematic, as the necessary funds were not available at the national level and had to be sought from international sources.

Aim and Objective

A priority of the National Development Plan of Namibia is the socio-economic improvement of the rural population by improving their access to public services and infrastructure such as health care facilities, education, transport, water and energy.

In view of this goal, the Ministry of Mines and Energy, supported by GTZ, launched a programme on the “Promotion of the Use of Renewable Energy Sources ” in 1993.

Project Background

Project Planning

The approach of this programme was not to create a new implementation unit in the Ministry, but to integrate RE into existing structures, programmes and responsibilities.

GTZ advisory focussed on two levels:

- Support for sector policy in facilitating co-ordination, creating framework conditions and incentive schemes which allow commercial dissemination processes and stimulate technology transfer (White Paper on Energy Policy in Namibia);
- Information and advisory services for programme managers and market players.

In the case of Namibia PV systems were introduced as cost-effective means of supplying electricity to health centres and schools and for supplying drinking water to off-grid areas.

As a result, the PV option is now integrated in the planning procedures of the Department of Water Affairs and the Ministry of Works. Since 1997 more than 50 health centres and schools were equipped with PV systems and more than 100 photovoltaic pumps were installed for rural drinking water supply.

But the real challenge remained the supply of the private households with least cost electricity by SHS by a market-oriented dissemination approach.

In the case of Namibia, the strategy for SHS dissemination focused on 5 activities:

- Increasing the **awareness** of the population by means of demonstration units installed at rural clinics and schools as well as by nation-wide campaigns in all public media,
- Creating a countrywide installation and maintenance network by means of **training** local electricians, living in rural areas close to the potential customers
- Establishing an appropriate **credit scheme** to provide loans to rural consumers willing to purchase a SHS.
- Levelling the field for a price and quality competition and consumer protection: This means minimum **technical requirements** for SHS components had to be defined for dealers and suppliers that want to benefit from the financing scheme.

There is not much of innovative know-how required to implement the single activities, but the real challenge is to gear these and a few more activities in a concerted way. This approach has to organise several independent actors: hardware suppliers, providers of financial services, political level and last not least the customers. It makes for example no sense if a financing scheme is in place but this financing scheme suffers from high default rates caused by low quality products and non-existent after sales service. Monitoring of the progress and the impact of SHS dissemination was essential to focus of intensity the activities.

Since no national experience on SHS dissemination was available, a pilot phase with approx. 100 SHS was launched in 1996 to provide the background information for the design of the dissemination strategy. The findings from the pilot phase revealed, that local availability of skilled manpower, sound solar companies as system suppliers, as well as private ownership of the SHS and avoidance direct government subsidies are crucial success factors for the sustainable dissemination of SHS in rural areas.

The so-called *Home Power! Program* [4] was then launched in all 13 provinces of Namibia in 1997 and implemented in four annual phases up to 2001. Each phase was subject to a public tender to select accredited suppliers. This tool revealed to be effective in order to stimulate a price & quality competition in a premature market. The technical specifications were adjusted from phase to phase with the progressing experience. Furthermore the program widened the scope of offered PV systems to meet the demand of the clients.

[4] An interesting element of the approach is the combined offer of **SHS and LPG** cooking systems aimed at compensating one of the main disadvantages of a SHS, namely its limited power generating capacity, which is not sufficient for thermal applications like cooking and ironing. Consequently, the *Home Power! Programme* offers a combined PV-LPG system covering the most urgent energy needs of rural households.

PHASE		Phase 1 (Pilot Phase) (1996/97)	Phase 2 (1997/98)	Phase 3 (1999/2000)	Phase 4 (2000/2001)
Systems offered by the HOME POWER Program	A B C D E	50Wp 4 lamps	5 Wp lantern 50 Wp 4 lamps	5 Wp lantern 50 Wp 4 lamps 100 Wp 8 lamps	50 Wp 4 lamps 100 Wp 8 lamps 150 Wp 8 lamps+inverter 250 Wp 8 lamps+inverter+fridge
SUPPLIERS TENDERING		4	6	6	5
SUPPLIERS SELECTED		1	4	4	2

Project Description

Awareness Campaign

- **Energy demand**

Based on discussions with representatives from villages and local authorities, inventory studies were carried out to analyse the actual energy demand and supply situation of the target groups and the local administration. Thus, the needs of the rural population for electricity services such as lighting, TV, radio and tape recorders could be assessed. So far, these needs were mostly covered by traditional means such as candles, kerosene and gas lamps for lighting, dry-cell batteries for radios and tape recorders and, in very few cases, car batteries being re-charged in the next rural centre for TV operation.

During the pilot phase, one standard SHS was offered with an installed capacity of 50 Wp. Some potential customers asked for a cheaper system, and a 5W solar lantern was added in phase 2. However, only 9 lanterns were sold in this phase, but more people asked for larger systems. It became obvious that the clients eligible for a loan from the Revolving Fund were more on the high end of the rural households' social layers. Therefore the choice of systems was extended up to a 250 Wp SHS including inverter and fridge.

- **Information**

With the target groups and their needs (demands, expectations, anticipations) being identified, a public awareness campaign was launched in 1998 under the heading *Home Power! Program*. The campaign included advertisements in newspapers, local radio stations and the national TV programme, expositions of material on-site and discussions with potential users. It was found that most rural families were not knowledgeable about the options of decentralised electricity supply, therefore the campaign was repeated twice, increasing the degree of awareness and, hence, the demand considerably.

- **Demonstration**

In order to demonstrate the mode of function of a PV system to the potential rural customers, schools, agricultural extension service centres and rural clinics were selected and equipped with SHS. These systems were installed in 1996 in collaboration with the Department of Works responsible for the equipment of these institutions. Late, the Department continued with the installation programme on its own, and up to 1999, 40 clinics and 30 schools have been equipped with PV systems.

Project Financing

The high upfront investment for a SHS (from USD 900 for a 50Wp system up to USD 3500 for a 250Wp system including all fees for handling, administration, transport, installation and insurance over 5 years[5]) exceeds the financial capacities of most rural households. It was therefore essential to provide appropriate credit facilities.

With the commercial banks being rather reluctant to cope with small-scale loans in rural areas, the project established co-operation with the Namibian Development Corporation (NDC). NDC had some experience with financial services in rural areas and supports a number of branches in various provinces. A ***Peri-Urban and Rural Solar Electrification Revolving Fund*** was established by the Ministry of Mines and Energy in 1995, jointly financed by the Namibian government and foreign donors (REFAD, NORAD) and administered by NDC. In June 2000 the total contributions to the Fund amounted to approx. NAD 5.5 million (USD 900,000) of which a small portion (NAD 150,000) is being used for a credit guarantee fund.

NDC plays the role of the fund manager and is also responsible for the administration of the bank accounts of the project. NDC and its regional offices provide the information brochures and the loan application forms to interested clients identified by the technicians and evaluates the loan application according to their proven standards. The conditions for eligibility include a minimum regular income and a positive record upon previous loans.

Rural customers could apply for a credit from this fund to purchase a SHS from the accredited suppliers of the HOME POWER! Program. After approval by NDC, the customer is requested to make a down payment of 20% of the purchase price of the SHS of his choice.

80 % of the investment is given as a credit with 5% annual interest rate to be paid back over a maximum period of 5 years. With a 5 year loan period the monthly instalments for a $50W_p$ SHS amount to NAD 70 (USD 12.50). In order to consider the income patterns of the customers, the debt service could be made in monthly, quarterly or annual instalments. After the pilot phase it was found that a down payment of 20% was too much for most of the customers. Subsequently the down payment was reduced to 10% of the purchase price and the monthly instalments for a 5 year loan period increased from 70 to 80 NAD.

Once the down payment was registered by NDC, the installation took place. The supplier and the technician were paid in full by NDC after presentation of a certificate of delivery, and the customer had then to pay back his loan in instalments according to his choice.

Project Installation and Maintenance

- **Training of technicians**

In order to create an initial structure for local installation and maintenance, about 100 local technicians from all provinces of Namibia were trained in PV technology. The trained technicians were certified in order to become eligible for the town-based solar companies as retailers and installers of SHS. They are paid on a per system basis.

- **Identification of customers**

It is the task of the local technicians to inform potential customers about the prospects of SHS. They are further requested to help people to fill in the loan application form and to deliver it to the nearest NDC branch office. As a return on their efforts, the technicians are entrusted with the installation work.

- **Selection of suppliers**

In each phase the systems were subject to public tender according to NDC procedures, taking into account quality aspects as well as prices. Through this procedure, prices could be kept nearly stable during the four phases of the program. The first tender for $50W_p$ systems was

[5] Insurance covers damages resulting from Acts of God only.

awarded in February 1996 at a unit price (excluding transport and insurance) of NAD 4490 (USD 750), the last one in May 2000 at NAD 5018 (USD 836).

- **Installation of systems**

Once the loan application has been approved by NDC and the customer has made his down payment, the installation takes place, jointly organised by the technician and the supplier. It was agreed that each technician is performing the first installations under close supervision of the accredited supplier. If the supplier agrees that the quality of work, the technician is entitled to install SHS on his own with the material being shipped to him by the supplier. The installation fees range between NAD 600 (USD 100) for a $50W_p$ SHS and NAD 1200 (USD 200) for $250W_p$ PV system.

After completion of the installation work and the performance test of the system, the customer has to sign a certificate of completion to be presented by the supplier and the technician to NDC for payment.

Project Impact

Socio-economic and Ecological Impacts

In order to evaluate and compare the socio-economic impact of rural electrification by extension of the central grid and by decentralised power supply by SHS, a study based on surveys of 371 rural households has been undertaken in the framework of GTZ's project monitoring[6]. It could clearly be shown that lighting is main energy service followed by ironing (grid electrified households only) TV/ radio and refrigeration (grid). Electricity used for cooking is limited to about 30% of the electrified households, who are using electricity occasionally for cooking (see graph 1, last page of paper).

When asked about the indicators of change in the daily life, about 90% of the electrified households announced their satisfaction about an increased level of safety and cleanness. 50% of the households indicated improved health conditions, and about 12% of the electrified households reported that the improved quality of lighting has led to better working conditions for school children, men and women (see graph 2, last page of paper). No significant difference between grid- and off-grid electrified households could be observed.

However, the home based income generating activities were reportedly undertaken also in unelectrified households and have only been facilitated, but not initiated by electrification.

The survey results indicated that indoor pollution could be reduced by substituting kerosene lamps and candles by electric lights. However the major source for indoor pollution is still the fuel wood used for cooking purposes. There were also no clear indications yet about the reduction in the consumption of dry cell batteries for torches, radios and tape recorders.

On the other hand an environmental risk caused by lead acid batteries must be taken into consideration, and a compulsory recycling system has to be established to minimise this risk.

Lessons Learned and Success Factors

Technical Aspects

The potential customer can choose between four different types of Solar Home Systems, ranging from a 50 Wp SHS with four lamps to a 250 Wp SHS including inverter and fridge. It was found that a 5 Wp solar lantern offered during phase 2 of the *Home Power! Program* apparently did not meet the customers' demand (only 9 lanterns were sold), whereas the large 250 Wp system was quite a success with more than 40 systems sold within 6 months. In a sample survey undertaken in 1998, most customers stated their satisfaction with the technical

[6] GTZ/EDRC: a. a. O.

performance of the system and the after sales service provided by the local technicians[7]. However, many were not satisfied with the capacity the system. Apparently they were not properly informed about the limitations of a SHS compared to grid electricity.

Hence it seems that the technicians do not discuss the users' concerns about the capacity of the systems in adequate detail. Besides technical aspects, training must put more emphasis on user information, marketing and business development. According to information received from the suppliers, only about 10 technicians have proven successful so far and are now able to install SHS independently. In one region, four have recently formed an association to share the work. The biggest problems encountered by local technicians are transport and communication.

It appears that the local SHS suppliers are competent in terms of the ability to supply and install systems, although standards are still missing and ongoing maintenance is a problem due to the long distances. The SADCC/TAU aims to develop a regional code of practice covering system design, installation and performance. Certification and standardisation of components will be tackled in the near future by the newly to be established "Renewable Energy and Energy Efficiency Institute", which is at present under investigation.

There is the capacity in Namibia to manufacture DC refrigeration units and PV pumps, as well as balance of system components such as inverters and charge regulators. These components are produced on a batch basis and on request. Batteries and modules are usually imported from South African agents or direct from international manufacturers.

Financial Aspects

The credit recovery rate of the revolving fund is high with arrears of only 6% of the loan amount paid out. According to the latest status report from NDC from October 2000, the status of the revolving fund is as follows [8].

REVOLVING FUND (TOTAL)	NAD 5,549,747
Loan Amount Paid Out	NAD 3,694,980
Amount Received	NAD 1,100,447
Outstanding Balance	NAD 2.374,477
Arrears	NAD 220,055

However, the overall demand for SHS did not meet the expectations, apparently the ownership model is only suitable for a minority of rural households who can afford such systems. Since 1996, there were only about 400 loans granted, distributed as follows:

SYSTEM CONFIGURATION	A (5W)	B (50W)	C (100W)	D (150W)	E (250W)
NUMBER OF SYSTEMS FINANCED	9	234	80	29	44

Thus it can be clearly stated that a revolving fund managed according to banking principles offers the following advantages and limitations:

- High pay back rate with a low percentage of arrears

[7] GTZ/EDRC: Socio-Economic Impact of Rural Electrification in Namibia,
Report 1: Comparison between Grid, Solar and Unelelectrified Households

[8] NDC: Solar Energy Project, Status Report 31 October 2000

- Good sustainability of the fund
- Restricted number of potential customers
- No access to the rural poor

Such a market oriented approach has therefore to be complemented by other dissemination strategies to set up a large scale rural electrification programme, if it is intended to provide electricity services to all rural customers.

So far there are no direct subsidies paid out of the revolving fund, but the preferential interest rate of 5% p.a. charged on the outstanding amount is about 15 points below the market rate. Over a pay back period of 5 years, this adds up to a subsidy element of about 31%.

The Way Forward

The principles of private ownership, locally available service and reliable PV systems resulted in a good degree of customer satisfaction, leading to an high credit recovery rate within the revolving fund. On the other hand, the selection criteria for customers eligible for the credit facility and the high costs are a limiting factor for the wide spread utilisation of SHS, limiting the potential customers to the high income groups of the rural population.

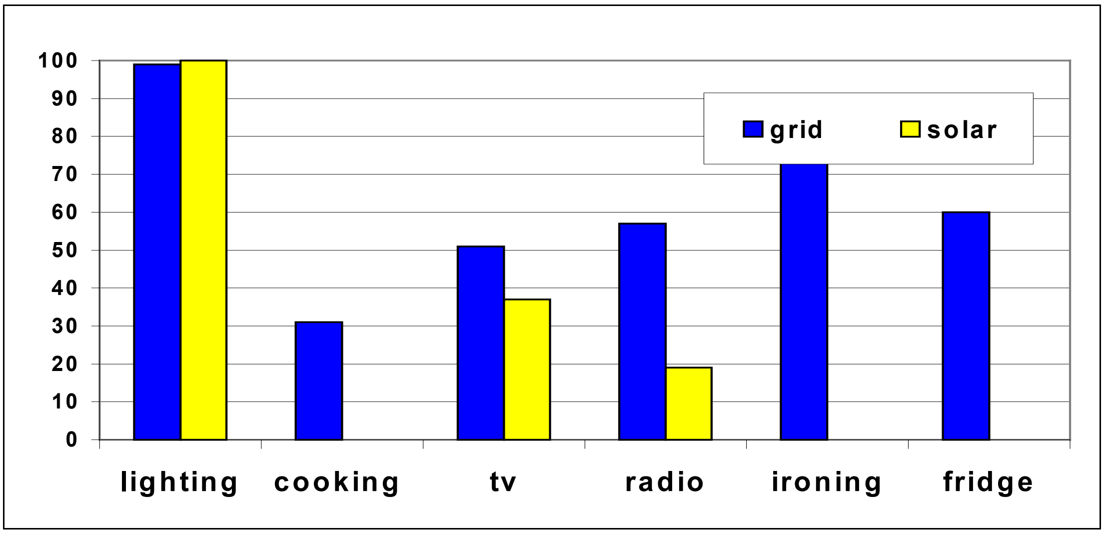
In order to overcome these restrictions and to better fulfil its tasks as an energy service provider not only for customers connected to the grid, but for all Namibian citizens as specified in the Energy White Paper, the state owned power utility NamPower has launched an extensive Rural Electrification Master plan. In a first step, grid- and off-grid areas were clearly identified by using quantitative and qualitative indicators such as

- Distance to the existing grid
- Number of households in a certain area
- Schools and clinics
- Economic growth points

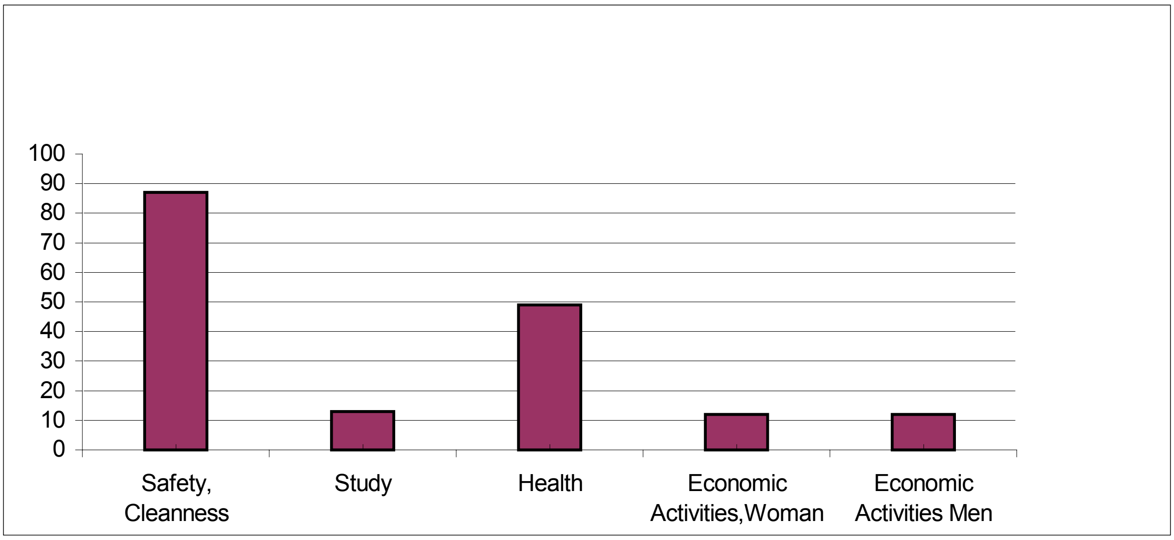
As second step, NamPower will elaborate on the most appropriate large-scale implementation strategy for off-grid electrification, taking into account the results of the *Home Power!* Program as well as testing the acceptance of the fee-for-service model as applied, e.g., in South Africa. For this purpose, three regions have been selected, where 50 SHS per year shall be installed in each region by one or several local service providers, who remain the owners of the systems and will charge the end-users with a fee for service. In parallel, the option of purchase of a SHS on credit by making use of the revolving fund is still maintained.

In order to continue the monitoring and evaluation of rural electrification by means of SHS, it is intended to perform a comprehensive survey on the technical performance of the systems installed as well as on their socio-economic impact. Based on the results of the surveys, further conclusions concerning the role of electrification for the economic development and the social welfare of people as well as the mode of delivering energy services to remote rural areas can be drawn.

Graph 1: Electricity End-Uses (% of households)



Graph 2: Improvement of Living and Working conditions (% of households)



2.8 PV Electrification of Rural Schools in South Africa

Case study prepared by R. Oldach, IT Power, UK

Introduction

The project described in this Case Study provided PV systems, including lights and audio visual (AV) equipment, for 1000 schools in remote areas of South Africa. Whilst many South African cities and towns are fully developed with modern infrastructure and energy services, a large number of people in the rural areas do not enjoy the benefits of being connected to the electricity grid. The South African government, together with the electric utility Eskom, are working on extending the grid in the rural areas. In parallel to grid extension, PV is used to electrify schools, clinics and also households, mainly in areas where the grid would be least economic.

Aim and Objective

The objective of the project was to provide electricity to 1000 schools in remote areas of Northern Province and Eastern Cape Province in the Republic of South Africa, using PV systems. As part of the PV systems, each school was to receive lights and AV equipment. The electric lights would be useful in extending study hours, especially during pre-exam periods, but also during the day on rainy days. Electric lights would also allow adult evening classes to be held in the evenings, under the country's Adult Basic Education and Training (ABET) programme. The AV equipment would allow teachers and students access to educational TV programmes, and would also improve the standard of English teaching considerably.

Amongst water supply, transport and telecommunications infrastructure, electricity is seen as one of the most urgent needs for the rural communities, and is therefore part of longer-term development strategies.

Project Background

The project was funded by the European Commission. It was implemented by the South African utility Eskom, under the supervision of the Department of Minerals and Energy (DME) and with technical assistance from IT Power in the UK and the Energy & Development Group, South Africa. After the installation phase, the Department of Education (DoE) became responsible for the PV systems.

The project was the EU contribution to an existing government programme (Reconstruction and Development Programme, RDP) set up in 1995 to supply non-grid electricity to 16 400 schools in remote parts of the country. Prior to the EU project, over 1 400 schools had been electrified with finance from the government’s national RDP and from the Dutch government (300 schools) at a cost of approximately 12 million EUR. The EU-funded project commenced in December 1998.

Project Description

Project Financing

The project was funded by the European Commission and its total value was 15 million EUR. European Commission financing included capital and installation costs of the equipment, as well as technical assistance including capacity building and initiation of a maintenance programme, including maintenance for the first year. Costs for ongoing maintenance were not included in the European Commission financing, but were the responsibility of the DoE.

Technical Description

The main components of the PV system installed were an 880 Wp PV array, a charge controller, a 24 V battery bank and an inverter. Additional items included electrical protection equipment (e.g. circuit breakers, fuses, earth leakage detection), a display giving an indication of the state of charge of the battery, and several anti-theft and anti-vandal measures (e.g. steel enclosures, steel frame around the modules, tamper-proof bolts).

In addition to the PV equipment, lights and AV equipment was provided for each school (television, video cassette recorder, satellite decoder and satellite dish). The systems were designed to generate enough electricity to provide lighting for three to five classrooms and power for the audio-visual equipment. Electrical wiring of lights and sockets, including an electrical distribution box, was included as part of the PV installation package, as was the installation of the satellite dish.

Capacity Building

The Technical Assistance Unit (TAU) carried out capacity building at various levels. Within the DME and the DoE, technical and managerial support was provided to officials, leading to vastly improved technical capabilities and understanding of the issues involved. Similar support was provided to the relevant managers and staff at Eskom, both at Head Office and in the two Provinces.

Technical training was carried out for Eskom's commissioning personnel as well as for installation contractors and their staff, both in formal training sessions and more informally during field visits. Similarly, Eskom's extension workers, responsible for liaison with schools and training of teachers, were trained in formal training courses and on the job during visits to schools.

Quality Assurance Mechanisms

Eskom had developed procedures for both the testing of equipment and the installation and commissioning of systems at the beginning of the project. About one year after the start of the project, the TAU had been contracted and commenced its activities. Part of the TAU's remit was ongoing monitoring and evaluation of the project. During the initial months of the TAU's activities, serious shortcomings and obvious technical problems became apparent, including lack of quality control in equipment selection and approval, procedural short-comings resulting in variable quality of systems in the field, and variable levels of training for installers and users. Existing procedures had either proved inadequate or sometimes had not been followed at all. The results were evident in a high numbers of system failures in the field, and the long-term implication was higher operating costs or premature system failure.

In addition, analysis of feedback from the field indicated that theft and vandalism occurred to a much larger extent than previously realised, and were becoming a threat to the success of the project. Upon the TAU's recommendation, the DME called an internal mid-term review to address the problems discovered.

During the review, the issues identified were dealt with by the TAU in co-operation with Eskom and other stakeholders. Over a period of several months, design improvements, component matching and component testing were carried out, and a number of quality assurance processes were improved. To facilitate this, the TAU produced procedures for component checks, for battery storage and regular recharging, for installation, and for more detailed commissioning checks. Eskom and installation subcontractor staff was then trained in using the new procedures.

The basic principle of the quality assurance mechanisms put in place during the review was to follow documented procedures, and to record the results of all tests and checks carried out. Any shortcomings were recorded, to be rectified prior to completion of installation and handover of the systems. The TAU carried out spot checks as part of its audits, to ensure that procedures had been followed correctly.

Before the end of the TAU contract, the TAU carried out a set of final audits to check whether systems had been installed and commissioned correctly, applying the relevant procedures. It was found that the technical quality of the installations had improved greatly between the initial schools visits and the final audit visits. However, significant problems still remained at a number of schools at the time of the TAU's final audit. Due to delays with the installation process, the TAU contract ended several months before installations were complete, with significant numbers of installations still to be completed. Therefore at the end of the project a large number of installations were completed without any technical audit mechanism in place.

Measures to Improve Sustainability

The delay caused by the mid-term review enabled the stakeholders in the project to address a number of sustainability issues before the end of the implementation process, such as end-user training, long-term project responsibility, stakeholder involvement and maintenance aspects. This has improved the prospects for the long-term sustainability of the project significantly. The final level of sustainability achieved and hence the success of the project will be dependent on a number of factors, namely the technical quality of the installations, whether the DoE operates an effective maintenance scheme and makes funds available for this, and whether the stakeholders involved continue to perform their respective roles, particularly regarding effectively combating theft and vandalism.

- **Extension Worker Programme and Community Involvement**

In order to try and foster a community approach and good contact with teachers and communities, the EU funded eight Extension Workers (EWs), who were a key link between the beneficiaries and Eskom. The main functions of the EWs were:

- Liaison with communities and setting up links;
- Monitoring and reporting function;
- Promotion of security measures at the schools;
- Training of teachers in operation and maintenance.

The TAU supported the EWs, by making visits to schools with them, maintaining a dialogue with them and their managers, and providing input to various training and re-orientation courses. The TAU also initiated reporting mechanisms to allow feedback from each school visit to be recorded and analysed.

The TAU carried out a survey of schools, interviewing staff and community members on aspects of installation, operation, installer maintenance and their own care of the PV equipment, and assessing the overall impact of the project on the schools and the communities. The utilisation of the AV equipment for the school as well as for the community as a whole, for instance through evening classes or community functions, was encouraged.

Stakeholder workshops were organised, aimed to bring together key players in order to develop a realistic maintenance strategy, to address the issues of theft and vandalism and to stress the importance of community involvement. The workshops also aimed to inform DoE decision-makers about the benefits that the PV systems would bring to the schools in terms of helping to meet the DoE's priorities and policy objectives. The workshops involved participants representing the police, DoE, Eskom, schools, DME and the EU. The workshops resulted in the development of a Sustainability Action Plan.

- **Security**

Following the experiences during the first year of the project, as well as in previous projects, security was recognised as a major problem by all stakeholders. The TAU therefore implemented a number of security measures.

In addition to the array security frame and the steel enclosures provided, each school was expected to implement a number of security measures before the AV equipment was installed. These included fences, burglar bars on classroom windows and a night watchman.

Other strategies were investigated and taken forward, such as the utilisation of Community Police Forums and district teacher networks on security issues.

- **Maintenance and Handover to DoE**

Ongoing system maintenance is required to ensure that systems remain operational in the longer term. Short-term maintenance during a one-year warranty period was the responsibility of the installation contractors entailing two six-monthly site visits per school.

The TAU investigated different maintenance management options (e.g. fee-for-service), as well as likely costs of maintenance. A series of stakeholder workshops were held at which maintenance options were presented and discussed with the DoE. The TAU provided support in developing a maintenance plan to give optimum performance regarding quality, cost and speed of repair. The TAU also provided information on the maintenance requirements to the DoE.

The TAU liaised with the DoE on issues relating to handover of the system to them. This included transfer of stocks of spare parts previously held by Eskom. As the final version of the IMS was not available by the end of the TAU contract, a demonstration version was presented to the DoE by the TAU.

A technical manual, which had been prepared by the TAU as part of the review, was handed over to the DoE. This provided installation guidelines and information on the maintenance needs of the systems. It also provided information about fault-finding and could be used as a reference on any aspect of the system.

Impact of the project

The project is expected to have a significant impact on the education of school children in rural areas of Eastern Cape and Northern Province in South Africa. It is hoped that the PV systems will also have an impact in the respective communities, through adult education and communal use, for instance for functions or for entertainment using the AV equipment.

The improvements to the technical design, to installation and commissioning procedures, and the measures against vandalism and theft are expected to make the project considerably more sustainable than it was before. However, as the TAU contract ended before installations were completed, there are still some questions over whether all improvements were carried through as had been agreed.

Lessons Learned and Success Factors

Following lessons learned from this project, a number of recommendations are made for future PV electrification projects for schools.

Project Design

Future PV implementation projects or programmes should be designed together with key receivers at a very early stage in the decision-making process, so that it ties in with policy objectives of the receivers, and that the project is a priority for them. This should ensure the required buy-in and long term commitment of the key receivers.

For future projects, the project design should ensure that electrification is ‘Quality driven’ rather than ‘Quota driven’, i.e. the main performance indicator should relate to the quality of installations rather than to the number of systems.

Technical assistance should be built into the project activities at every stage, from the planning stages until operation and maintenance mechanisms are well established. This project would have benefited from technical assistance being available from its beginning, and until after handover of the systems to the DoE. The TAU began operating about one year into the project. By this time, not only had all equipment been selected and accepted, but several hundred systems had been installed. There were therefore severe constraints with regards to possible remedial actions to address the shortcomings which were discovered at the beginning of the TAU activities. The TAU contract ended several months before installations were completed. It would have been beneficial to have technical support as well as independent scrutiny until all installations were complete, and during the first few months after handover of the systems to DoE.

Institutional Issues

For future PV electrification projects for schools, electricity needs should not be assumed, but rather evaluated in co-operation with key receivers. Rather than to propose one single standard power supply for each school, it may be better to provide a range of services according to the types of school.

Key constraints such as theft and vandalism should be acknowledged and addressed at the project design stage, using social as well as technical solutions.

Effective ongoing maintenance is essential in order to ensure the medium to long-term sustainability of any PV project. This includes clearly defined fault reporting.

Quality Assurance Mechanisms

Technical reliability of equipment and long maintenance intervals should be key requirements. Vandal and theft proofing of each component should be given very high priority when equipment is selected, using existing technical solutions where possible. Testing of equipment and component matching should be carried out prior to final equipment acceptance.

Detailed procedures for acceptance testing as well as installation and commissioning checks must be provided, including clear guidelines for the documentation of these activities. These procedures must provide for any shortcomings to be reported, and mechanisms for their rectification prior to handover.

Reporting and monitoring is critical. It is strongly recommended that sufficient resources are allocated for these tasks. Monitoring activities should include the use of a computer-based Information Management System, which should comprise comprehensive and up-to-date data on all aspects of the project and include relevant existing information from other sources. It would then form a valuable tool for use during planning and implementation as well as for operation and maintenance.

Regular audits by an independent party are recommended, to ensure that procedures are followed correctly. An end of project audit after completion of the implementation phase is suggested, i.e. after installation, commissioning and all related activities such as training have been completed.

2.9 Resource-Conserving Irrigation with Photovoltaic Pumping Systems in Chile

Case study prepared by R. Posorski, GTZ, DEU

Introduction

An increasing scarcity of usable agricultural land, coupled with the consequently rising costs of leases and property, often force farmers to move to areas with little infrastructure.

Far from the electric grid, the customary means of pumping irrigation water are diesel or petrol pumps. These have the double drawback of requiring much and expensive maintenance and depending on a regular supply of fuel, so that they cannot be operated unattended. Especially in remote areas of developing countries with inadequate spare parts and maintenance structures, diesel and petrol pumps are often inoperable for several days. The resultant lack of water can seriously damage crops, reducing yields and income. Hence, using conventional pumping systems poses an economic risk to farmers. Moreover, the noise and exhaust from such pumps impact on the environment. The pollution of ground water and soil by diesel fuel and lubricants is no rare occurrence.

Environment-friendly, low-maintenance photovoltaic pumping systems (PVP) provide new possibilities for pumping irrigation water, but still constitute a little-known technical option, especially in the agricultural sector.

Aims and Objectives

The objectives of the PVP programme were to:

1) Prove how photovoltaic pumping systems can be used to irrigate high-quality crops in a cost-effective and resource-conserving manner,

2) Determine the managerial and technical requirements for operating a PVP irrigation system.

Project Background

Supported by the favourable experience gained in a large International Demonstration and Field-testing Programme for PVP, proving the viability of PVP to supply remote villages with drinking water[9], the PVP Irrigation Pilot Project was initiated by the German government.

The pilot project, financed by the German Federal Ministry for Economic Cooperation and Development (BMZ), is being implemented by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, the government's technical cooperation agency. In cooperation

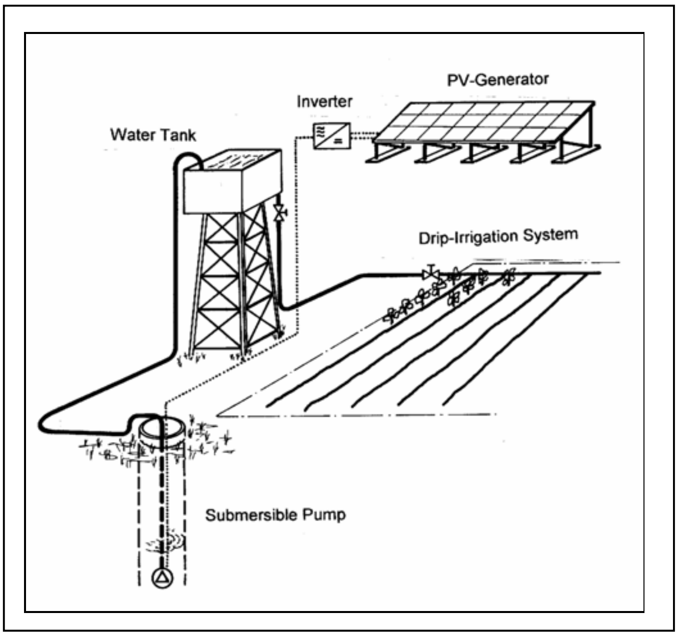
[9] A case study on this programme is also available.

with the partner countries Ethiopia, Chile and Jordan, ten pilot installations on private and public sector farms are producing cash crops and undergoing intensive monitoring.

Project implementation started in 1998 and finished in 2002. The counterpart in Chile was the University of Tarapacá.

Project Description

This case study concentrates on the installations in Chile. Here the project focused on peri-urban small and medium-size farms that use energy and water-conserving forms of irrigation to grow cash crops on up to 3 hectares of land, generating income that could be used to finance a PV-based irrigation system. Four pilot plants (0.3-1.2 kWp) for cash crop production have been installed in the Atacama Desert in northern Chile.



The interdisciplinary character of the PVP Irrigation Pilot Project called for close co-operation with experts from various disciplines. To induce sustainable dissemination processes, suppliers of PVP irrigation systems and their local partners or companies are being involved in the project activities. The project also co-operated closely with national and private sector institutions.

The field-testing of PVP irrigation systems enabled the users and operators of the pilot facilities to assess and evaluate the technology. Therefore the project placed great emphasis on training of project partners and system users.

Key measures implemented have been:

a) Site selection, ordering and commissioning of PVP systems;

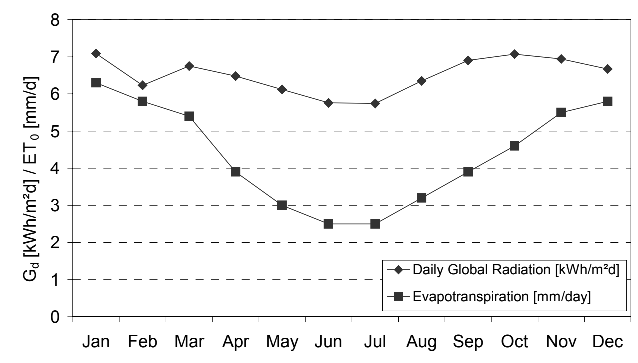
b) Monitoring the PVP systems and the irrigation system;

c) Selecting and testing components matching the requirements of PVP irrigation systems;

d) Training of users to manage the PVP irrigation systems;

e) Analysing the cost-effectiveness of PVP irrigation systems;

f) Study on environmental impacts of PVP and diesel pump systems.



Recorded daily global radiation (G_d) and evapotranspiration (ET_0) at pilot site Chaca, Atacama Desert, Chile

Lessons Learned

Technique

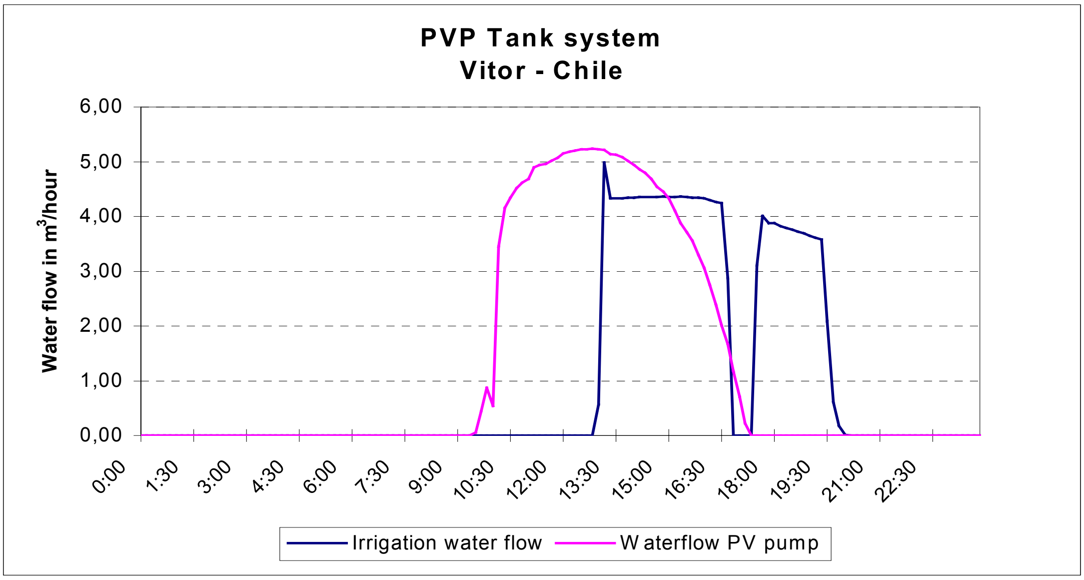
- **Technical Monitoring**

To permit continuous monitoring of crucial operating parameters, all pilot systems have been equipped with automatic data acquisition systems. In addition to the technical evaluation of the performance of the PVP irrigation systems employed, the recorded meteorological parameters facilitated the management of the irrigation systems, and the water consumption data provided information on the degree of system utilisation.

- **PV-irrigation Systems**

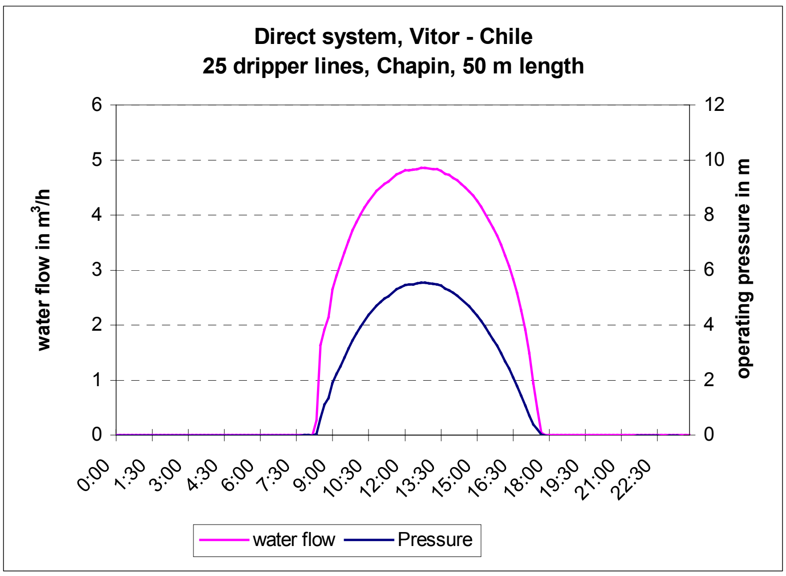
Two different system configurations have been employed within the scope of the project. In the first case, a solar generator produces electricity to drive a submersible motor pump, which pumps water into an elevated tank. The tank serves as an energy store and supplies the pressure needed for the irrigation system. The stored water can bridge periods of low insolation and supplies the pressure needed for the irrigation system. Pilot plants equipped with a water tank operate at considerably low system pressures, compared to conventional diesel or petrol pumps. This presumes, of course, that all components of the irrigation system have been designed for such low pressures.

PVP tank irrigation systems operate at constant pressure of approximately 0.2 – 0.5 bar depending on the height of the water tank and with a rather constant water flow. Irrigation is regulated by hand valves.



In the second case, the PVP injects the water directly into the irrigation system. As pertinent experience in Chile shows, this can reduce the initial capital outlay by as much as 35%. However, due to daily fluctuations of global radiation, these systems operate at variable system pressures and water flows.

One major advantage of solar pumps is that they do not require batteries, which are expensive and need a lot of maintenance.



The maintenance of a PVP irrigation system is restricted to regular cleaning of the solar modules. Depending on the water quality, the only moving part of the system, the submersible motor pump, has to be checked every 3 to 5 years.

Drip irrigation saves a considerable amount of water compared to other irrigation techniques. Furthermore, it has a rather low operating pressure. Both features reduce the energy demand and make drip irrigation particularly suitable for photovoltaic pumping systems.

Unlike other irrigating processes, drip irrigation is amenable to a continuous supply of water, so the pump can run incessantly through the entire growing season. Since both the crop's water requirement and the output of the pump are functions of the global radiation, the two systems go hand-in-hand up to a certain point. However, the output capacity of the PVP must be designed for the maximum water requirement.

On a yearly average, though, each and every difference between the actual demand and the supply of water detracts from the system's overall degree of utilisation. In that sense, conventional motor-driven pumps are more flexible. The daily output of a motor-driven pump depends not only on its rated power, but also on the easily adaptable time of operation. Therefore diesel pumps can cope with most fluctuations of demand.

The better the crops can assimilate the quantities of water actually supplied, which of course vary according to daily and seasonal fluctuations in insolation levels, the more economical a PVP will be. Since different crops have different water requirements, and since those water requirements fluctuate in the course of the growth cycle, the proper choice of crop successions and combinations is of decisive importance to the degree of utilisation of solar pumping systems. Uninterrupted crop rotation patterns or continuous cropping systems with high value added crops (e.g., cash crops such as fruit, vegetables, herbs and spices) are especially suited to irrigation by a PVP system.

- **Research and Development Requirements**

While the technical aspects of solar irrigation are generally regarded as adequately developed, a closer look reveals that laboratory and field research is still needed.

The main field of application for PVP are wells and boreholes with larger pumping heads. But for irrigation purposes mainly surface water pumps are required, which still have to be developed or optimised for PV.

Up to now conventional drip irrigation systems have been combined with PVP. Contrary to electric or diesel pumps, PVP systems have variable operation characteristics. This requires the development of low-pressure drip irrigation systems suited to operating under such variable conditions, including suitable filters and fertilizer injection devices.

Drip irrigation systems are not always locally available in developing countries. Research for alternative low-pressure irrigation systems might overcome this constraint.

Economic Aspects

The costs of photovoltaic irrigation are measured against the additional profits gained by the agricultural or horticultural production unit. Consequently, it is not sufficient to simply compare the costs of the competing technologies, i.e. PVP and diesel pumps. Rather, the overall profitability must be investigated, taking agro-economic aspects into account.

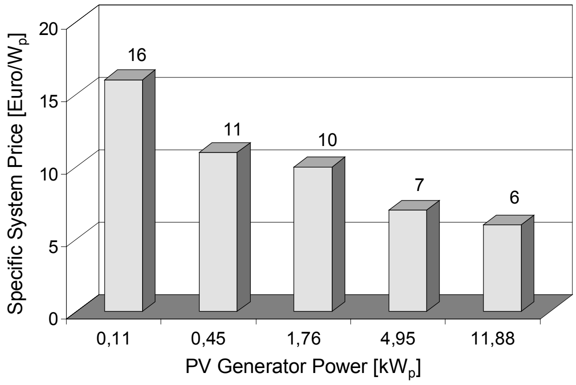
The economic analysis is limited to an assessment of the microeconomic advantages of PV-based systems and alternative diesel or petrol pumps. In this case study, no macroeconomic aspects are examined. The acquisition of data and the subsequent economic analysis comprised four steps:

- At first all data of relevance to the economic analysis at the project sites were collected.
- The second step was to calculate, on the basis of a dynamic cost annuity approach, the water pumping costs incurred by the competing technologies. The specific water pumping costs [€/m^4] are used as the criterion to compare both technologies.

- As a third step, the cost analysis was followed by a profitability analysis that allowed agro-economic aspects to be taken into account.
- In the fourth and last step, general conclusions were drawn from the findings of the site-specific economic analysis.

- **Investment Costs**

Ready-to-run PVP presently cost approximately three times as much as diesel pumps of comparable performance. In Chile, photovoltaic pumping systems are locally available. Consequently, the corresponding market prices were used for the economic evaluation.



However, national and local constraints can have major impacts on the initial cost of investment. For example, in Ethiopia import duties and other charges increase the basic import price of a photovoltaic system by 47%, while in Chile they are a mere 5–10%.

The high output-specific outlays for PVP are comparatively high financial burdens on farmers who opt for photovoltaic irrigation. Hence, many farmers decide in favour of diesel-driven systems. What they often fail to see, though, is that once a PV-based system is in place, it costs only a fraction of what it costs to operate a diesel pump.

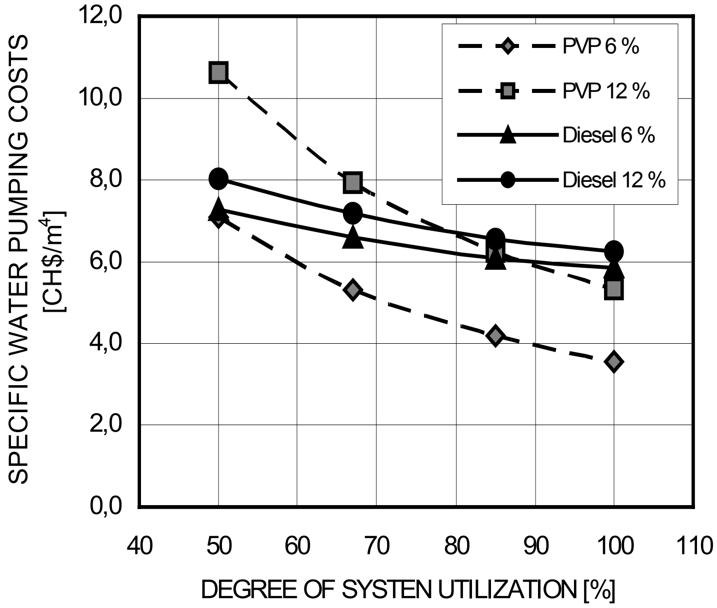
- **Water Pumping Costs**

The specific **water pumping costs** are the main criterion for an appraisal of different pumping technologies. These are the costs caused by a pumping system, taking investment costs as well as running costs into account, to supply one cubic metre per day at a pumping head of one metre. They are expressed in \$ per m^4.

The costs have been calculated on the basis of annuities, using a country-specific, inflation-adjusted calculatory interest rate, and taking into account the service life of the respective component.

The specific water pumping costs depend not only on the pumping head but also on a number of other site-specific parameters, which must be accounted for. This makes it difficult to apply the results to other sites and to make generally applicable assertions regarding economic efficiency. The main parameters in question include:

- System output;
- Solar irradiance;
- System configuration (PVP system with or without storage tank, motor pump or generator with submersible motor pump);
- Operating mode (automatic irrigation or by manual control, motor pump with or without standby generator);
- Discount factor;
- Useful life of individual system components;
- Degree of system utilisation.



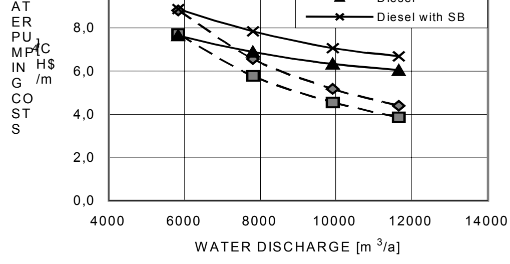
The overall costs of a PVP system are much more dependent on the system's rated output compared to diesel pumps. The latter can, for a given rate of consumption, be designed for a higher peak demand without incurring much additional cost. The figure above illustrates the specific water pumping costs [CH$/m^4] for the project site in Vitor/Chile.The installed PVP system is compared with the smallest available diesel pump as a function of the degree of system utilisation for different interest rates.

High degrees of system utilisation are necessary to make PVP economically viable. Since the diesel system has a lower investment cost, the water pumping costs react less sensitively to interest rate changes. For low interest rates, the PVP option is economically superior, even at a low rate of system utilisation (50%). At the postulated maximum interest rate of 12%, costs equality is achieved for a utilisation rate of approximately 80%.

The next figure illustrates the effects of different operating modes on the specific water pumping costs for variable water discharge rates. High water discharge rates correspond with high degrees of system utilisation for a certain pump. A standby unit was included with the diesel system in order to compensate for its inferior technical reliability. This increases the specific water discharge costs by 10–18%. A PVP system without a storage tank presents an average cost advantage of 15%.

Generally PVP systems tend to be economically viable with a real discount rate below 12% p.a., a degree of system utilisation above 60% and an irrigation area smaller than 4 ha.

At higher latitudes the field-cropping irrigation season lasts only five months. There PVP will be economically disadvantageous, since a degree of system utilisation in the order of 30% must be anticipated.



- **Profitability of Irrigation**

As a rule, irrigation is employed to get additional benefits from agricultural or horticultural production. Therefore, the additional income achieved should outweigh the costs of irrigation and allow for a sufficient profit or amortisation of the investment. In the project area, agriculture is not possible without irrigation. Hence the overall costs of agricultural production (including the cost of the water supply) were compared with the sales proceeds achieved for the pilot sites in Chile.

The model calculation of revenues and input costs for various cultures was performed for an average cropland area of 3 hectares using field and statistical data. The results revealed that irrigated farming is highly profitable in northern Chile. The internal rate of return on the capital inputs (soil, wells, irrigation system, etc.) exceeds 70%. The portion of costs of irrigation accounted for a surprisingly low 4–6% for most of the crops analysed. Hence, cost advantages gained via one or the other pumping technology have a small effect on profits.

While the farmer operators of PV-based systems appreciate their superior reliability and the potential for automating their irrigation systems, such advantages are difficult to express in monetary terms. Consequently, most investment decisions tend to favour diesel pumps over PVP systems. That drawback may be compensated, and the farmers' financial risk minimised, by way of appropriate financing and assistance models.

Management Requirements

The production management of a PV-based irrigation system is somewhat more complicated than that of a conventional pumping system due to daily and seasonal fluctuations of the solar insolation.

One of the most important site-specific cost factors is the degree of system utilisation, which is the ratio between the average and the maximum annual water production. This factor will always be below 85 % since fallow periods between the growing periods and the alternating water requirements of the crops at different growth stages don’t permit better system utilisation even under optimised conditions.

Once the system is installed, one of the farmer’s main management tasks is to plan the cropping and the irrigation in order to reach a maximum degree of utilisation. As a rule, this entails a change in how the farm is managed. The resultant changes in timing and work routines can be crucial for the acceptance of PVP technology.

Nevertheless, Chilean farmers, who are used to facing daily problems with their diesel pumps, greatly appreciate the high level of reliability and low maintenance requirements of PV irrigation systems. That fact alone contributed much to the acceptance of this new technology.

Environmental Impacts

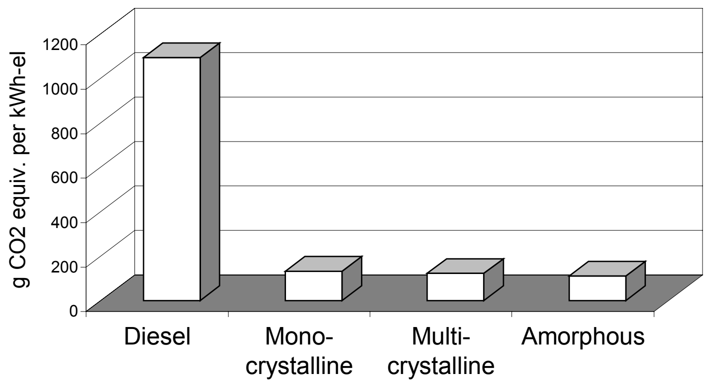
- **Life Cycle Analysis of PVP and Diesel Pumps**

A project study conducted in cooperation with the German Institute for Applied Ecology analysed the environmental impacts of photovoltaic and diesel pump irrigation systems on a life cycle basis.

The study incorporates a calculation of greenhouse gas emissions (as CO_2 equivalents), acid air emissions (as SO_2 equivalents) and cumulated energy requirements (CER). Qualitative environmental impacts, such as the pollution of water and soil by diesel oil, were also analysed. Finally, energy productivity factors and energy payback times of three PV technologies (monocrystalline, multicrystalline and amorphous silicon modules) have been determined.

The life cycle comparison is performed for conditions in sun-rich developing countries (assumed solar irradiation 2000 kWh/m²/year) and analyses the so-called “cradle-to grave pathway” that includes the manufacturing process, transport, operation and partial recycling of system components.

The results of the life cycle comparison show that the greenhouse gas emission balance of PV pumps is approximately 10 times smaller than that of the diesel system. For acid air emissions, diesel and PV systems differ by a factor of at least 50.



- **Energy Productivity Factors and Payback Times**

The energy productivity factors and energy payback times are further indicators of the environmental burden resulting from solar modules. The energy productivity factor is defined as the quotient of the total energy supplied by an energy system during its lifetime and the total manufacturing energy input for this system.

The energy payback time is calculated by dividing the energy-specific manufacturing input for an energy system by the amount of energy it supplies annually. It corresponds to the period after which an energy system has "paid back" the energy used for its production through the energy it supplies. Both factors are comparatively favourable for PVP in sun-rich regions.

In summary, PV modules are significantly less of an environmental burden than the diesel reference system, even with conservative assumptions regarding module lifetime, rack and frame construction. In the life cycle comparison with fossil fuel systems, the foreseeable improvements of PV manufacturing technologies will further increase their advantages.

Perspectives

Although photovoltaics still counts among the most expensive ways to utilise solar energy, it has already found its way into numerous agricultural and horticultural applications, many of which are economically attractive. PVP in particular constitute an alternative worth considering if the object is to pump irrigation water to crops at locations with no access to grid power.

The project experience yields the following conclusions:

- In order to reduce the energy requirements of PVP irrigation systems water-conserving and energy-saving micro-irrigation techniques have to be applied.
- The plot size for PVP irrigation should be below 4 hectares.

- High rates of system utilisation are necessary to achieve economic viability of PVP irrigation systems.
- Therefore PVP systems are limited to irrigate permanent crops and continuous crop rotation in arid climates.
- High value-added cash crops like fruits, vegetables and spices should be given preference to recoup the high initial investment.
- Low-interest loans should be available for the same reason.
- PVP irrigation systems require a careful planning of the crop schedule and are more demanding of user skills.

A site-specific economic efficiency analysis should always be performed prior to any investment decision. Despite their indicated limitations, solar irrigation systems are bound to gain importance in the future, primarily by virtue of their low environmental impact, high reliability and lack of dependence on fossil energy sources.

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2.10 Water Desalination Powered by PV System in Syria

Case study prepared by H. Senba, Shikoku Research Institute and T. Nakajima, Japan Photovoltaic Energy Ass, JPN

Introduction

Population (un-electrified population)

According to the statistical data from 1999, the total population of Syria is estimated as 17.5 million and the average annual population growth rate is over 3 %. In 1998, 8 751 villages out of 12 121 villages were electrified by the grid network and the electrification rate was 72 %. On the other hand, about 3 000 villages do not have public water supply services. The south-east of Syria is a particularly arid area, where the population is about 700 000. Out of 700 000, Bedouin account for more than 90 % of the population, or about 650 000 people. The security of supply of their drinking water is a priority subject to study.

Economic Situation (GDP, Structure of industry)

The annual GDP of Syria is USD 16.7 billion and GDP per capita is USD 1 070 (assumption of IMF in 1999). The economic growth rate is about 2.5% and the inflation rate is about 1.5 % (assumption of IMF in 2000). The structure of industry is as follows; 54.3 % is service industry, 27.8% is agriculture, 13.7 % is mining and industry and 4.2 % is construction. The export total is USD 3.14 billion and main export products are crude oil and oil products, fruits and vegetables, textile and so on. The import total is USD 3.31 billion and main import products are machinery, metals and metal products, foods and chemical products.

Energy Structure (mainly situation of water resources)

The breakdown of power stations by energy source is as follows; 42 % is thermal power, 26 % is gas turbine, 13 % is combined cycle and 19 % is hydro power. The total capacity of the power stations is 2 996 MW and power demand is 18 200 GWh. On the other hand, water resources are said to be about 25 billion tons, of which surface water and ground water are assumed to be about 22 billion tons and three billion tons respectively. The water demand in 1995 was 14.4 billion tons (13.6 billion tons for irrigation and 800 million tons for household use). However, water demand in the country is predicted to keep rising to 17 billion tons in 2000 and 23.5 billion tons in 2025. It seems certain from these figures that there will be a shortage of water in the near future. Already such phenomena as lowering of ground water levels in wells and deterioration of well water quality are noted. Energy and power concerns are managed by the Ministry of Electricity and water concerns are managed by the Ministry of Utilities and Housing, the Ministry of Agriculture and the Ministry of Irrigation.

With regard to renewable energy, SSRC is the main body carrying out research and development. However the only projects currently underway are a wind power station under consideration in the coastal area, a Pilot PV system by UNDP, various PV systems by JICA which are centralised, some individual DC & AC systems and a water pumping, desalination and portable SHS project for Bedouin by the FAO.

Aim and Objective

PV systems were introduced in areas around Aleppo, Syria to promote rural electrification and introduce groundwater pumping systems and brackish water desalination systems for demonstration. Installation, operation and management of these demonstration facilities and development of a cottage industry are executed to enhance the livelihood of the people of the rural areas. Through this study, it is intended to verify the feasibility of PV systems in terms of technology, economy, finance, society, organization, management and environment. Furthermore, technology transfer, from designing and installation to operation and management, will be carried out with the counterpart in Syria.

Project Background

History of the Project

Syria has vast arid areas mainly in the southeast. Most of the villages in rural areas, including those in arid areas, are small-sized villages located far away from grid lines and wells. As for public services, such as supply of electricity and water, from an economic viewpoint extension of the grid and installation of a water supply system cannot be expected in the near future. This is because a large capital investment would be required. In August 1994, under these circumstances, this project was started around Aleppo, which is the second largest city in Syria and about 400 km north from the capital, Damascus. This development study includes the introduction of rural electrification by PV systems, the introduction of groundwater pumping systems and pumping/desalination systems and the enhancement of the livelihood of the residents of rural areas through the utilization of electricity and such systems.

Related National Governmental Policies

Ever since the fifth five-year plan (1981), the government of Syria has been pursuing elimination of interregional differences as one of the general objectives of the national development plan. In line with this aim the electrification plan is set up to enhance the standard of living of the rural area villages. The government of Syria has a strong interest in the use of renewable energy resources, especially solar energy, as a means of promoting rural electrification. On the other hand, the construction of waste water treatment facilities etc. is being promoted to secure new water resources.

Project Planning

A social and economic survey of unelectrified villages around Aleppo was conducted. On the basis of the findings of the survey, a centralized PV system and a water pumping system powered by PV are installed and operated in Zarzita. In Fedre and Katoura, individual small-scale PV (DC) systems are installed and operated. In Rasem Al Shikh Kalif, individual medium-scale PV (AC) systems and a water pumping/desalination system are installed and operated. Next, through the experiences of operation and management, maintenance and inspection, efforts are made to develop a plan concerning the sustainability of the introduced facilities, method of operation and management and organisational system. Furthermore, the introduced PV systems were analysed in terms of technology and economics and future introduction plans of such systems and the role of the government of Syria were studied. Recommendations were made to meet the present conditions and to rationally integrate new PV systems into the electrification plan and the water supply plan.

Project Description

Project Technical Description

- **Outline of Introduced Facility**

The outline of the desalination system in Rasem Al Shikh Kalif is shown below. Regarding the method of desalination, RO (Reverse Osmosis) was selected because there are many practical results, composition of facilities is simple and maintenance and management is comparatively easy.

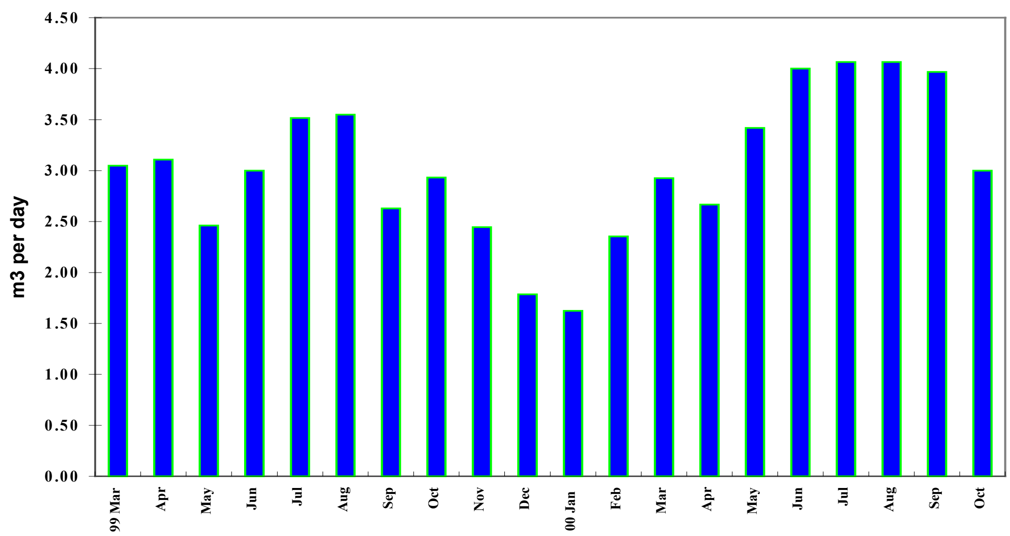
Type of system	No. of system	Outline of main equipment
Water pumping system (Start of operation : Aug 1998)	1	PV array 1.9kW Inverter 1.5kW Submergible pump 20m^3/day, etc
Desalination system (Start of operation : Aug 1998)	1	PV array 8.6kW Inverter 10kW Battery 24kWh(20 x 12V-100Ah) Desalination unit RO Design capacity : 12m^3/day/24hours TDS*(Well Water) : 2,345-5,500ppm TDS(After desalinated) : 45-108ppm Result of operation : 1.5(Jan); 4.1(Jul)m^3/day Raw water tank:30m^3 Desalinated water tank:10m^3

*TDS: Total Dissolved Substance

- **Operation Status of Desalination System**

The daily average production of fresh water in each month is shown below. This shows that about 1.5 m^3/day of fresh water was produced in winter, whereas about 4 m^3/day in summer. On the other hand, regarding the performance of the desalination system, there is a big seasonal variation of the well water salinity. The analysis results indicate the salinity of well water were 7,290 ppm in August and 4,540 ppm in October 1998, and 3,200 ppm in February 1997. However, regarding the quality of fresh water, salinity of desalinated water was between 80 -100 ppm and satisfied the initial design condition.

Figure 1: Quantity of fresh water production per day



- **Fees Collection and Distribution of Water**

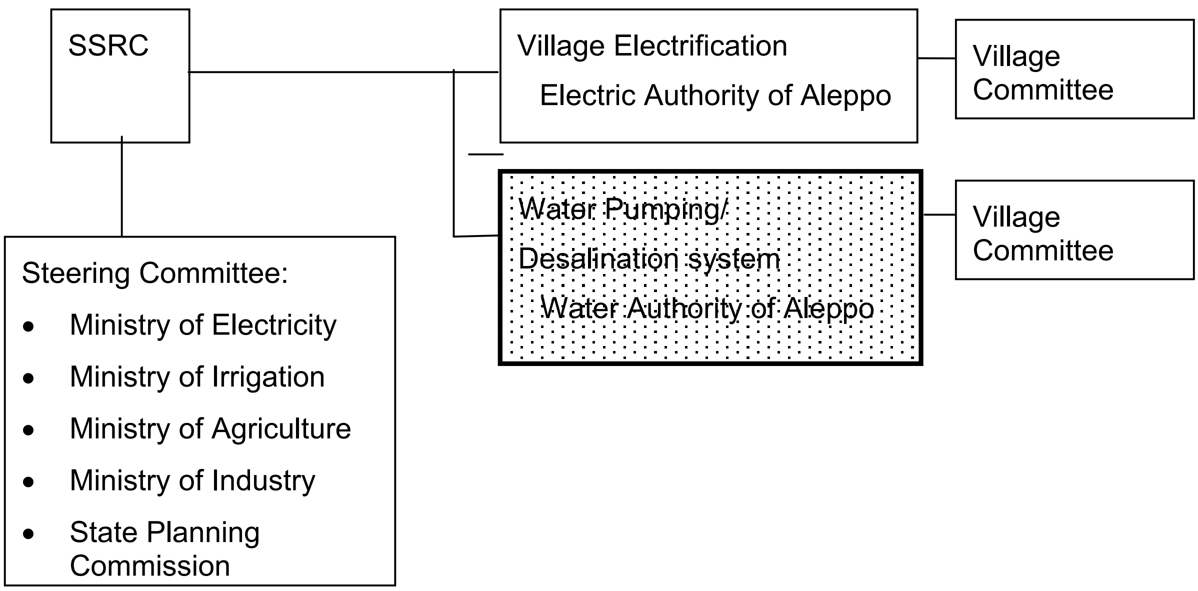
The Water Authority of Aleppo began a fee collection for the fresh water supply. The fee was set at 7.0 SP/m^3 for the beneficiaries (1USD = 45 Syrian Pound). A contractor who is from the village carries out the fee collection on behalf of the Water Authority and 6.5 SP/m^3 goes to the Water Authority of Aleppo. The minimum amount of fresh water necessary for an adult each day, for drinking and cooking use only, was presumed to be about 6 litres in winter and 10 litres in summer. The actual amount of water to be distributed for each person would be decided based on these figures. However, the total time of operation fluctuates seasonally. The operational hours of the desalination system in the summer season are as long as 8 hours/day or sometimes more and about 4m^3 of fresh water is produced on average. The population of the village decreases to about 30 people in summer because many of the villagers have to be away from the village for nomadic herding. Therefore, most of the fresh water would become surplus if the allocation continues to be set at 10 litres / person. As a result and in order to use the produced fresh water effectively, there should be storage as much as possible in a reservoir in preparation for water shortages. Also, if there is still a surplus of water, it should be distributed to villages other than Rasem Al Shikh Kalif and a fee collected.

Project Financing Plan

This project was a JICA development study. Therefore, the main system components introduced which were a desalination system, PV modules, inverters etc. were procured by JICA. On the other hand, the installation cost, including some materials, was covered by SSRC and the Water Authority of Aleppo.

Project Infrastructure and Institutional Issues

The organisation of this project and the organisation with regard to the desalination system are shown below.



- **Technology Transfer**

The counterpart is SSRC. The technology transfer consisted of system design, installation, operation and maintenance and was carried out for SSRC through OJT (On the Job Training), seminars and workshops by the JICA team. After that, with regard to village electrification, technology transfer was carried out for the Electricity Authority of Aleppo and with regard to desalination systems it was carried out for the Water Authority of Aleppo by SSRC. Both of these Authorities are carrying out system management under the technology assistance of SSRC.

- **Management , Operation and Maintenance**

Daily Maintenance

The Water Authority of Aleppo is responsible for managing operation and maintenance of the desalination system. The daily management of operation and maintenance is carried out by the villager who is educated by the Water Authority. The villager in charge reads various operational data while the system is stable, about 1-3 hours after the start-up of the operation every day, records the data on a fixed form, checks the operation situation of the system overall, and does necessary maintenance work.

Periodical Maintenance

Periodical maintenance has to be conducted by the engineer of the Water Authority of Aleppo who is in charge of the management of the system. After technical training by SSRC for the engineer is completed, the engineer has responsibility to make a periodical maintenance.

Emergency

In the case of an emergency, the Kalif Villager in charge of daily maintenance contacts by phone the person in charge of operation and maintenance of the desalination system in the Water Authority of Aleppo. The responsible person who receives the report gives the necessary instructions to the maintenance person and goes immediately to the site, depending on the situation.

- **Education and Training System**

Engineer of SSRC

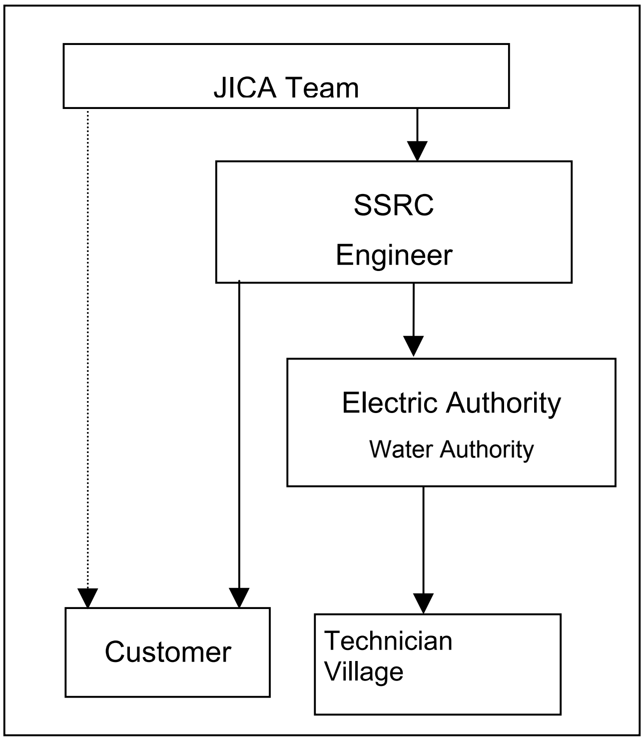
Training of the SSRC engineer was carried out as part of the technology transfer of the project. The comprehensive technology transfer was carried out and covered the areas of system design, installation, operation and maintenance, measurement data analysis, economic analysis and procedure of village survey.

Engineer of the Electric Authority and the Water Authority

SSRC engineers carried out the technical training for the engineers of both the Authorities through seminars and OJT at installation and trial operation.

Technician of Village Committee

The engineer of the Water Authority carried out training for the village committee technician who is entrusted with the management of the desalination system. The training was technical training regarding operation and training on management and fee collection.



- **Long Term Sustainability**

The operation and management manual and facility ledger was provided, and technology transfer for operation and maintenance was completed through OJT etc. Therefore, there should be no technical issues regarding system management in the future. Also, spare parts for the main components are available and expendables such as chemical products are available in the local market. A fee for water is collected. However, the collected fee itself does not cover the whole cost of operation and maintenance. It is necessary to subsidise by the budget of the Water Authority.

Awareness

Before introduction of the system, village meetings were held and educational activities were carried out for the villagers. The contents were advantages and disadvantages of a PV system, outline and usage of a desalination system and so on. Moreover, the village committee was organised and given information regarding operation and management through installation and trial operation. Additionally, the village committee was asked to cooperate in fees collection and management.

Target Groups

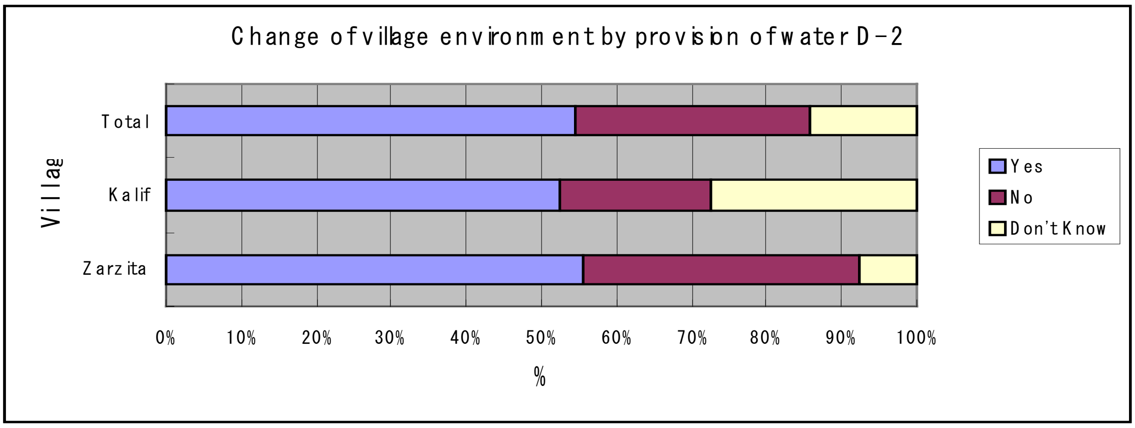
The desalination system powered by a PV system is most suitable for use in such regions in Syria where no electricity is supplied and the supply of fresh water is not enough. The need for this kind of system is particularly high in areas like the Badia area, which is a very arid area in Syria. In these areas there are few large towns and cities because most of the people in the region are Bedouin who live on livestock raising. The number of people living in Badia is about 700 000 and Bedouin accounts for more than 90 % of the population, or about 650 000 people. There are only a small number of fresh water wells, public and private, the water quality of which is acceptable by drinking water standards, and most of the Bedouins have no choice but to use more or less salty water, the salinity exceeding the standard value.

On the other hand, improving Bedouin's life would contribute to stabilisation and development of Syria's livestock raising industry. The grid extension into the Badia area could hardly be expected unless the number of those who settle in the region increases. Therefore, the Badia is regarded as a promising region for future development of PV water pumping and desalination systems. However, from the viewpoint of the limited demand for water, the opportunities for the expansion of desalination systems powered by PV system will have to be developed in other areas in addition to Badia.

Impact of the Project

Social Impact

Before the introduction of the water system, the villager relied on rainwater and commercial water. After the introduction they benefited a great deal from the acquisition of a water source, although it still did not supply a sufficient quantity of water to meet their needs. Moreover, the health situation in Kalif was improved by securing drinking water that passes standard.



In case of the desalination system in Kalif, underground water was pumped in a quantity several times greater than that of the desalinated water. The excess water was used for growing salt resistant crops such as olive, cotton and wheat. This water was used for drinking water of animals as well.

Economic Impact

In Kalif, before introduction of system, the villagers paid 50 SYP/m^3 (including transportation fee) for buying water, but the new fee for water was set at 7 SYP/m^3. Therefore, the villager's expenses for water were reduced significantly. From the viewpoint of security of water resources for living, the effect of living improvement and benefit of the villagers was satisfactory. (1 USD = 45 SYP)

Environment

In the Kalif system, the condensed water mixed with raw well water to return suitable salinity contents, making it usable for many purposes. In Kalif, yearly rainfall is about 300 mm, therefore this multi-purpose water is available to use for irrigation, because diluting effect by rainfall is expected. Thus, there will be no salinity contents problem for the soil.

Lessons Learned and Success Factors

Lessons Learned

- **Institutional and Infrastructure Issues**

In the year 2000, the Higher Committee for Energy was established. This Committee responds to tasks such as the World Energy Conference. Also, a subcommittee for petroleum, gas, nuclear and renewable energy is under consideration to be set up in this committee. Hence, to diversify the energy sources in the future, Syria has been promoting demonstrative studies of the use of renewable energy such as wind power generation and PV systems. Thus, it is essential to establish a policy without delay and promote its development. As the use of renewable energy relates to various Ministries, it is hoped that a new organisation will be established to unify policy and develop and operate renewable energy systems.

On the other hand, for the introduction of renewable energy systems it is necessary to cooperate not only with the Ministries concerned but also with the local government for promotion activities. Technical aspects such as research and development, operation and maintenance and software aspects such as planning, management and fees collection also have to be addressed. Also, in the future, the engineer who carries out the system management and the planner who makes an introduction plan, will be required to train and make arrangements not only with the Ministries concerned but with the local government also.

- **System Management in Cooperation with the Villagers**

To make good use of PV systems in the future and in order to reduce the cost of system management, the relationship of cooperation with the target villages by the system management organisation must be further built up and developed.

- **Promotion of Technology Development and Cost Reduction**

For the expansion of PV systems cost reduction is important. Technical development of PV modules and charge controllers and technology improvement in battery production is carried out by the mutual cooperation of the public and private sectors in Syria. It is necessary to reduce the total costs of PV systems by shifting to domestic production. However, at present since the desalination costs are so high an emphasis should be placed on the survey of the technical development conditions of the reverse osmosis membrane method, electro-dialysis method and the evaporation method using solar thermal, as well as on technical development such as prototyping and improvement. It is envisioned to reduce desalination costs based on those technical developments. On the other hand, at the present time it is necessary to import the main materials. Therefore the consideration of the institutional aspects such as import taxes for PV system materials and the simplification of customs clearances are necessary in order to promote material import.

- **Application for Sea Water Desalination**

More serious shortage of fresh water in Syria can be foreseen because of a possible restriction in using river water, a relative decrease in the groundwater reserve, etc. Seawater desalination is one of the most reasonable measures against this situation. The RO membrane method is the most economical way of making fresh water out of relatively high salinity water, and is regarded as the best technology to be used for seawater desalination. However, because the grid line has already been widely extended in the coastal area, it would be reasonable to use PV system not as the main power supply but as a supplementary power system.

Summary of Success Factors

- **Technology Transfer to the Engineer**

This project was executed over six years. The technology transfer was carried out for the necessary components for PV system project development, which includes site selection, system design, installation, operation and maintenance, education and project evaluation. Technology transfer was also carried out regarding the new applications for PV power systems, which are water pumping, desalination and cottage industry.

- **Basic Technology of PV System Concerned**

In Syria, a research institute already exists to investigate PV systems. This research institute is the counterpart of this project and carried out system maintenance and technology instruction to the organisation concerned. The basic technology of the PV system concerned existed in Syria from the beginning of project, this fact was important for the promotion of this project.

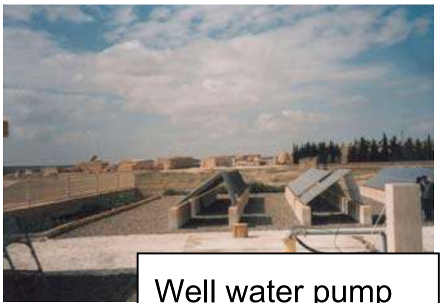
- **Establishment of Fees Collection System**

Regarding the fee collection, the organisation and system chosen decided that a contractor who was chosen by the Water authority in Kalif would carry out the management of water distribution and fee collection from the customers.

Photos of Desalination System


Whole view


PV array


Well water pump


Desalination unit


Water tap

2.11 Solar Energy for Health Improvement in Mozambique

Case study prepared by H. Tikkanen, NAPS Systems Oy, FIN

Project Background

Since 1995, Mozambique has been implementing a Health Sector Recovery Programme, and in 1997 the Government of Mozambique received a grant from Norway towards the cost of a Health Sector Recovery Programme project, “Solar Energy for Rural Health Facilities”. The project consists of photovoltaic electrification of approximately 250 rural health facilities. Systems will be installed in all 10 provinces in Mozambique, and relevant training of clinic staff of the maintenance organisation of the Ministry of Health is included in the delivery. The project is being carried out in two phases, Phase 1 and Phase 2, of which the first was under implementation at the time of this report.

Project Description

Technical Description

During the installation monitoring, health centres were visited, the hardware was inspected, the diagnostic measurements were carried out, and the staff was interviewed. At the time of survey, installations had been carried out at 10 health centres, and eight of these were visited. Every health centre will in principle have 4 independent subsystems; one health centre lighting system, one vaccine refrigeration system, and two staff house systems.

All staff interviewed expressed great satisfaction with the lighting system.

All 8 vaccine refrigerators inspected were stocked with vaccine, the batteries were without exception fully charged at the time of inspection, there are thus no concerns regarding the functioning of the vaccine refrigeration systems.

Typically health centres supplied under the project are supplied with two houses for the staff and their family to live in. These houses are also electrified in the project, as it is hoped that this will strengthen the motivation of the staff to take good care of the systems and make it easier for the Ministry to recruit qualified staff. The staff house systems provide lighting and are also equipped with a 60 litre domestic refrigerator.

In all instances the inhabitants said they valued the staff house systems highly. In particular, they like to have light that is free of charge and smoke and smell-less. The appreciation and awareness of the benefits of the domestic refrigerator appeared to vary more. It would therefore be appropriate to evaluate the impact of the presence of the domestic fridges after approximately three years. It appears that the portable solar lanterns have received a more mixed reception that the fixed light installation. The usefulness of the lantern in the context of the total system may be questioned.

The state of charge of the batteries in the staff house systems showed larger variations than in the systems installed in the clinic building. The most likely cause for the very low states of charge observed is clearly too high-energy consumption. In two of the three cases inhabitants had moved in after installation, and had thus not received any training and information.

Institutional Issues

Largely unforeseeable developments related to personal health and career, together with significant delays in customs clearance of the hardware, upset the orderly preparations for implementation of the project and led to a hesitating start-up. It is judged that the co-ordination between the supplier's representative and the Maintenance Department has been strengthened considerably by appointing a manager from the maintenance department to follow the installation team on site during the installation of systems numbers 11-20, an arrangement that may be continued for the entire phase1.

Capacity Building

Two installation courses have been held so far. The trainer reports that the average de-facto academic level of the trainees was slightly higher than anticipated, and that they did not have any problems with the technical matter taught. Most of them were also quite good at the practical exercises. The general attitude of the participants towards attending the course and the project was mainly good. The bulk of the provincial maintenance staff receives training through the projects, and it is not expected that there will be any problems related to their understanding of the systems.

Spare Parts

The institutional framework for spare parts has been changed since contract signature. The existing infrastructure and organisational capabilities at the provincial levels are reported to vary. The Maintenance Department is presently working on improving its infrastructure and capabilities with regard to handling of spares through the project "Support to the Maintenance Sector of the Ministry of Health" financed by the Government of Finland.

Operation and Maintenance

The daily operation of the systems will be the task of the Health Centre staff. The findings from the survey suggest that it is desirable to repeat these instructions at intervals for the next 2-3 years. This is due to the fact that the systems introduce new pieces of equipment to the staff, that the systems offer new opportunities to them, and that staff is changed from time to time. The Ministry of Health must take the main responsibility for training of the Health Centre staff. The organisation of the continuous follow up on systems and re-training of staff will be an important issue to consider. It is proposed to implement a system for data collection relying on established routines for reporting from the health centres.

Lessons Learned

Institutional

Although the project organisation was not working satisfactorily at the time prior to installation work, the formal organisation of the project is now in place and functioning as expected. A consistent implementation of the project in the remaining 30 health centres appears to be safeguarded by the <u>appointment of a supervisor from the Implementing Agency in Maputo.</u>

<u>The installation courses held seem to have been both appropriate and well conducted.</u> However, the training programme is far from completed. Better co-ordination between the client and supplier could probably have reduced the delay. Health Centre staff have received instructions, but the names of the persons having received it has not been recorded. The survey clearly uncovered a need for intensive re-training at this level during the next few years. This must be the responsibility of the Ministry of Health.

Installation Work

In general the systems have been installed in a satisfactory manner. Components have been securely fixed and the cabling is neatly run. Efforts have been made to avoid shading of the photovoltaic panels. There is evidence that the workmanship has improved as the installation team has gained experience.

Spares left on site generally were limited to lamps. This is not considered to be adequate. Every health centre should be equipped with fuses and distilled water for the batteries, and the staff must be instructed about how to use it. These items are not included in the supply contracts and it is therefore the Ministry of Health that must see to these issues.

Systems have been installed in buildings that were not designed with solar energy in mind. Due to local conditions relating to topography and architecture it will in many cases be almost necessary to strike a compromise between optimal module orientation and the feasibility of mounting them. In some cases (e.g. Manhique) it may be appropriate to also move the battery box when this is done to shorten the cabling between modules and battery.

In order to avoid shading, panels may sometimes not be mounted where it might have been most convenient to do so. In a few cases this has resulted in long cables between the panels and the batteries, which may impair the performance of the system by forcing the PV modules to operate far from their maximum power point. The use of a thicker cable (10 mm^2) must be considered during installation work in such situations in the extension of phase 1 and during the implementation of phase 2.

At some sites the electrolyte level was lower than maximum. At other sites the density of the electrolyte, which reflects the state of charge, was lower than expected. This may be due to using the loads too intensively, so that more energy is consumed than is restored during the daily charge phase, or to dilution of the electrolyte by topping up with distilled water. It is not possible to ascertain the reason without monitoring the systems over time. Nevertheless, the instructions for filling the batteries must be followed to the letter, which entails filling them to the maximum level with acid and topping up with more acid after the oxide on the electrolytes has reacted with the acid. It seems that the procedure for filling and installing batteries has improved as the team gained experience.

Tool-sets were always present but did not always have the same contents. The tool set was often stored in the battery box. Short circuiting a battery is a potentially serious mishap, and therefore metal objects should not be kept in the battery box.

In no case did we observe any significant problem with a vaccine refrigerator system. It therefore appears that this system is conservatively dimensioned, and it is likely to prove to be easy to maintain in operation.

Re-training

The quality of the instruction given to the health centre staff was difficult to assess. In one case all the staff present during installation had been transferred to other health centres at the time of the installation monitoring. In two cases the person responsible had gone to the District Health Administration to report statistics. At most sites the staff present answered that they had been given instructions regarding operation of system and checking of electrolyte level in batteries. They had usually not been instructed how to change fuses, but were often perfectly aware of what a fuse is. Nevertheless, there is evidence to suggest that constant re-training of the staff with regards to operation and maintenance will be important during the next 2 or 3 years in order to ensure the best possible exploitation of the different systems. The Ministry of Health through its organisation at the province and district level must assume the responsibility for training and re-training of clinic staff.

Conclusions and Recommendations

Actions Proposed for the Supplier

1. The contract provision (Memorandum of Pre-Award Negotiations), that the Installation Team shall liase with the Provincial Health Director regarding selection of sites is to be taken literally. As a minimum, the Employers Representative shall be present during installation work.
2. Panels must be mounted according to the technical specifications. In the instances where this is not the case, panels must be reoriented or installations extended to ensure a satisfactory performance all year round.
3. Installation teams should have material available for filling damages around holes in walls.
4. While the installation teams have taken measures to reduce the impacts of shading, mounting the panels a little higher or more to one side than done could in some instances have reduced this problem even further. Shading, even partial, should always be minimised. In instances when panels and batteries have to be installed far apart, the installation team should have adequate cable available for complying with the stipulated voltage drop between batteries and panels. The team should also have extra cable available for the installing the loads in the health centre lighting system.

5. Another issue relating to installation is the commissioning of batteries. The factory instructions for filling should always be followed to the letter. It may be a good idea to always install panels and batteries first and connect them, and then go on to install the loads. This way the batteries will have a few days available for charging before any loads are connected. It should be verified that the tool sets have their original content, and they should not be stored in the battery box.
6. The double-sided tape for mounting the circuit breakers in the battery boxes does not appear to be up to the job. It should be replaced.
7. The names of all staff members at the Health Centres having received instructions must always be recorded.

Actions Proposed for the Trainer

1. In the installation course it is important to stress the importance of avoiding shading, even partial (one shaded shell means that the entire module is not charging), of panels. It is also important to make it clear that panels must be installed facing north, with only small deviations being acceptable (the misunderstanding that has lead to the installation of panels facing west is NOT due to any errors in the first course held).
2. The maintenance courses must provide more in depth insight on the individual components than the installation course.
3. Training of maintenance technicians must include decommissioning of batteries.

Actions Proposed for Ministry of Health

1. All health centres should be equipped with spare lamps, fuses and distilled water. Installations already made should be upgraded in this respect. The clinics must be supplied with suitable ladders for gaining access to the panels and for changing lamps. The ladders should be stored so that they do not facilitate theft of panels. Hand torches may also be useful for changing lamps.
2. It must be ensured at regular interval that the staff at each health centre know how to change lamps and fuses, and how to top up electrolyte batteries. This instruction is best given by the local maintenance technicians. During the installation phase the maintenance technician following the installations team may take larger responsibility for this than anticipated in the contract.
3. Staff should be instructed not to store tool sets in the battery box.
4. A system for follow-up of installations must be implemented. The provincial maintenance organisation must also devote sufficient attention to the need for re-training of health centre staff. A sheet with basic user instructions should be developed and distributed. This will be done in collaboration with the Procurement Advisor.
5. A logbook, where all actions taken in relation to the systems are recorded, should be placed at every health centre. The instructions for filling out the logbook have already been developed by Maintenance Department.

* Data on this case study is based on the following document: Solar Energy for Rural Health Facilities, Installation Monitoring Survey Report, Report for Mozambique's Ministry of Health, Kanenergi, Project No. 97/26, Revision No. 01

2.12 Solar Energy for Village Electrification in China

Case study prepared by H. Tikkanen, NAPS Systems Oy, FIN

Introduction

China is the largest developing country in the world with a total population of 1.2 billion. According to China National Statistics, the GDP per capita was about USD 800 in 2000 and the average annual economic growth rate has been 6.5% over the last 10 years. Although, compared to the total population, the unelectrified portion is quite small in China; the absolute number is very large. Today there are still 70 million people in China without access to electricity. Most of them live in remote areas where grid extension is not economically viable.

The energy structure in China heavily relies on coal, which provides more than 70 % of the total energy supply. The use of coal as the main fuel for energy production is one of the major causes of urban air pollution and deterioration of the environment. The Government of China is determined to adopt policies to re-structure its energy sector and encourage the use of renewable energy. Renewable energy is a critical component of China's long-term energy strategy for rural development. China has strongly supported small hydropower, biogas, small wind turbines and Solar Home Systems over the past 35 years, as economically viable solutions to provide energy and electricity to isolated rural populations.

Project Background

Shenge village is located 4000 m above sea level in the Tianjun County, Haixi region, in the Midwest of the Qinghai province in China. Despite improvements in road conditions made over the last few years, the small town is still today over 6 hours drive away from Xi Ning, the regional capital city. Climatic variations of the area, going from bitter winters to sweltering summers, demand a truly reliable power solution. The population is stable and there are about 350 inhabitants in the village today.

Shenge had suffered from energy problems for a long time. A river that once flowed next to the village was the only source of energy and there had been some local mini hydropower available, until the river stopped running. Today, where the river once was, there is nothing but a dried-up riverbed.

Aim and Objective

To provide a solution to the energy problem, a Photovoltaic (PV) mini-grid energy system was installed in Qinghai Shenge village with funding donated by the Finnish government.

Project Description

Technical Description

The project feasibility study was carried out in 1995 and actual installation and commissioning was completed in 1996.

All the village houses are now electrified by a single photovoltaic system that has an inverter converting the direct current (DC) generated from the solar modules, to alternating current (AC), which is normal for grid electricity. The houses are connected in a small mini-grid of their own but not to the main electricity grid.

The PV system, which has a total capacity of 7,5 kWp, produces power for local government offices and the basic needs of the village at all times. The electricity is used first to charge the battery, where the energy is stored for later use. This is usually in the evenings when the villagers return home. During the summer time when the young men travel long distances with the animals they raise, the total energy consumption is noticeably lower.

The system loads include lighting, televisions and radios, as well as a washing machine and other community equipment such as communication devices and a ground satellite receiver.

Power lines strung through the village from house to house, provide electricity for normal everyday consumption, however there are some restrictions. For example, the use of the washing machine is limited to two hours a week.

Project Financing Plan

The Solar Photovoltaic (PV) mini-grid energy system was installed in Qinghai Shenge village with donation money granted by the Finnish government, in a bid to provide electricity for nomadic people living in remote habitats.

Project Infrastructure and Institutional Issues

The formal collaboration for the project was between the Chinese Research Institute of New Energy Resources and NAPS and the Finnish Ministry of Trade and Industry.

The project was carried out in collaboration with the local Qinghai New Energy Research Institute (QNERI), which was responsible for the co-operation with the local regional government, and for the feasibility study in preparation for the project. Prior to the design of the system solution, QNERI reviewed the needs of the villagers and also the user equipment that was available at the village from when there had been some local mini hydropower available before the river dried up.

The installation was completed within a week, because the equipment cabin and battery banks had been constructed earlier. The villagers themselves built the equipment cabin and supplied the building materials. The building for the equipment was actually the most important new piece of construction in the village for a long time.

Capacity Building

The capacity building activities included a training session for local installers and for end-users in the village, which was carried out at the same time as the installation of the systems. Also, a five-member team from the local institute (QNERI) attended a one-week training session on solar energy technologies in Finland.

Quality Assurance

- **Spare Parts**

The original set of spare parts included some modules, controllers and some end-user devices like lights, and spare board for the inverter.

- **Operation and Maintenance**

The operation of the equipment is monitored daily. Operating instructions have been translated into Chinese. A young couple in the village has been recruited to take on the responsibility of the monitoring. Three times a day they record the readings of the equipment, which are then forwarded to QNERI using the recently acquired computer - the first computer ever seen in Shenge. If necessary, QNERI can send a technician to the village to address more complicated technical problems.

Impact of the project

Over the years, there has been little change in the demographic situation in Shenge village, though some similar nearby counties have doubled their population and with that the need for power. Shenge villagers are quite content with their life; some have refrigerators and VCRs in their houses.

In some cases they even feel privileged when the unstable hydro power plant failed to provide electricity to county level residents while they at the village level can get power from the PV system or the battery bank at night time and still enjoy lighting and entertainment. The river that once flowed next to the village has now completely dried-up.

Technical performance

Overall the technical performance of the system has been very good. However, there have been a couple of failures. One of these came in December 2000 when the output voltage from the inverter somehow increased to over 300 Vac, and some home appliances such as television sets were damaged by the high input voltage. The problems were solved by replacing the control board of the inverter through involvement of the local institute repair team. Now the system is running well.

System Monitoring

The QNERI, have the responsibility of monitoring the system on a twice annual basis. This includes evaluation of the loads, which might have increased through individuals adding new equipment to the system. Adding loads to the system should only be done through consultation within the village, since if the total maximum load becomes too high the successful operation of the system becomes difficult or impossible.

Environment

The QNERI also need to ensure that the final disposal of batteries is done in the proper way in order than any unnecessary environmental pollution is avoided.

Lessons Learned

Institutional and infrastructure

It was of utmost importance that the existing energy status of the village and the needs of the villagers were evaluated prior to any system design. This was due to the fact that there had already been some type of electricity available and therefore the villagers already had some local equipment such as lights. They also had some priorities regarding where the electricity was to be used.

The co-operation with local and regional authorities was carried out by the local implementing agency, QNERI.

Overall, the most important lesson learned was that for the project to gain acceptance by villagers themselves, they had to be allowed to define themselves, within the budget available, the actual usage and distribution of the power to the areas / applications they wanted. In this way the system could be designed so that its capacity would be used optimally.

Also it is noted that the PV system can not supply power to all the needs of the village, mainly due to distance and movement of farmers/herdsmen, and so approximately 30 % farmers have bought portable solar home system for DC lighting and radio, VCD or milk processing devices.

Quality Assurance

Special attention should be given to packaging and transportability of the equipment. Also, the availability of good quality local spare parts needs to be clarified as part of the process to enable smooth replacement of faulty appliances, thus ensuring proper operation of the installed system.

Installation Work

The villagers themselves built the equipment cabin and supplied the building materials, which made many things easier, compared to the option of having to transport all the equipment from the regional capital. The fact that there is no motor transport in the village, yaks being the usual means of transport, was also important to remember when planning the actual packaging of the shipped equipment, as individual boxes needed to be small and light enough to be carried by yaks.

Capacity Building

The need for re- training is obvious as the responsible people within the village may move away. The local institute therefore needs to organise an updated basic training session within next 2-3 years.

In addition to the regular training for installers, maintenance staff and end-users, the original training sessions need to also include plans for updated re-training and continued training of the local users. This will be necessary in order to prepare for when new people move to the village, as well as re-training for the maintenance staff / responsible persons, as some of them might move away from the village.

2.13 The Photovoltaic Market Transformation Initiative

Case study prepared by R. Gunning, IT Power, GBR

Introduction

The Photovoltaic Market Transformation Initiative (PVMTI) was launched by the International Finance Corporation (IFC) as an innovative investment facility designed to provide finance in private sector projects to encourage the market development for PV.

A total of 25 million USD of Global Environment Facility (GEF) funds are available for investment by the IFC in PV projects in India, Kenya and Morocco. The funds have been allocated by country in the following manner: 15 million USD is allocated for India and 5 million USD each for Kenya and Morocco.

Aims and objectives

The principal aim of PVMTI is to accelerate the sustainable commercialisation and financial viability of PV technology in the developing world. PVMTI aims to address market barriers by making available appropriate financing and stimulating business activity. The specific focus is to stimulate PV business activities in India, Kenya and Morocco. This is achieved through:

- Providing finance for sustainable and replicable commercial PV business models, according to individual business plans through a competitive bidding process.
- Financing business plans with commercial loans at below-market terms or with partial guarantees or equity instruments
- Provision of technical assistance (through the EMT) to PV businesses on planning, financing operations and technology.

Project Background

Project History

In October 1996, the GEF Council had requested IFC to appraise and implement PVMTI. After an international review and analysis of a short-list of six countries, IFC recommended investment of PVMTI funds in three countries: India, Kenya and Morocco.

In 1997, IFC appointed IT Power Ltd. and Impax Capital Corporation Ltd. to provide consulting and advisory services during the appraisal phase. The PVMTI investment strategy was initially designed by IFC staff and then refined by the IFC and their advisors during the appraisal phase. The appraisal phase also included a market analysis of the three chosen countries; an evaluation of the PVMTI business case; and a summary of the potential PVMTI deal flows.

Project Planning

Following two years of planning the PVMTI was launched by the IFC in June 1998 after the implementation plan was endorsed by the GEF, the primary funding agency. The duration of the PVMTI programme is 10 years, from 1st July 1998. The first investment was approved in September 1999 and at December 2000, six more business activities have been approved with further investments under consideration. Disbursements have commenced.

Countries Information

The individual PV markets and barriers are described separately for the three target countries. In all countries significant problems in the PV industry, for example, poor quality, lack of consumer awareness and low margins can be attributed to one or more of the six barriers. The first two are economic barriers: (1) technology cost and (2) availability of affordable finance. Then there are two skill barriers: (3) management skills and (4) technical skills. Finally, there are two policy barriers: (5) government policy and (6) standards and certification.

- **India**

The Government of India is committed to renewable energy development and has the overall aim to achieve a 6 % contribution to power generation from renewable sources by 2002. Awareness promotion, information dissemination, development of standards, operation of test facilities and international co-operation are among the objectives of the government. The responsibility for implementing several vital programmes in solar energy utilisation has been assigned to a financial and promotional arm, the Indian Renewable Energy Development Agency Limited (IREDA).

The annual PV market in India was approximately 10 MWp / year in 1997. Government PV purchasing and subsidy programmes have played a significant role in supporting the development of this PV industry. There are substantial incentives offered including subsidies in the form of financial support and cost sharing, a wide range of fiscal incentives, and concessional finance. However the market is characterised by:

- an unacceptably high incidence of system failure in the field - attributed to poor product quality, poor system integration, poor installation standards, absence of after sales service infrastructure and most importantly no user financial commitment to equipment supplied. There is however an abundance of experience and plenty of competence at all levels, what is lacking however, is motivation.
- Inadequate marketing, distribution, customer support and after-sales service; attributable to private sector markets being suppressed by subsidy programmes. Most of the PV shipment in the country is through the institutional market route, meaning that PV-manufacturers sell their products to various government organisations and other institutional sectors who then distribute these systems directly to beneficiaries. The market side, however, is strong and the techniques sophisticated as are the financing packages.
- General lack of consumer awareness of PV technology and its benefits.
- Dependence on end-user subsidy.
- Underdeveloped availability of consumer finance which is crucial to make SHS affordable.

One of the significant features of the present PV status in India is that there are several private sector industries competing in the areas of PV system manufacturing including design, assembly, installation and commissioning of systems. There are additionally over 50 small entrepreneurs largely undertaking supply and installation of PV systems and executing contracts.

Therefore the PVMTI programme aims to address the above market barriers. In this context PVMTI does not build up manufacturing capacity but focuses on:

a) establishing marketing and customer service infrastructures;
b) securing the involvement of financial institutions in delivering appropriate customer credit schemes;
c) ensuring quality of systems design and installation, by increasing technical resources and competence through training.

- **Kenya**

The Government of Kenya policy is supportive of PV but is not driving the PV market in Kenya. There is very limited financial support to PV from the government because of the many demands on limited resources.

The market is driven by the lack of electricity services in rural areas and the desire by most households for access to TV, radio and light. Only 2 % of households have access to grid electricity. From the Rural Electrification Master Plan, recently drafted, it can be concluded that in-roads into rural household electrification through grid extension is unlikely in the foreseeable future. New rural connections are only approximately 5 000 per year. As nearly 20 million people live in the rural areas of Kenya, the scope for PV systems is very large.

Kenya has one of the world's most developed free markets for PV. The number of installed PV solar home systems in Kenya is more than 50 000 and possibly as high as 70 000 (mid 1997). The total installed PV capacity is more than 2 MWp. The annual market in 1997 was estimated as 0.30 MWp/year, the vast majority of which was for small (< 25 Wp) systems often utilising 12 Wp amorphous silicon modules. The number of homes being electrified annually with PV in the rural areas exceeds that being electrified through grid extension by the electrical utility.

However the Kenyan PV market is characterised by the following:

- The vast majority of sales are for cash (sometimes with dealers acting as savings banks and collecting cash by instalments in advance of a sale). Other sales are with hire purchase made available from dealers. There is negligible borrowing from banks.
- Poor quality installations attributed to poor quality components, inappropriate system design and untrained installation technicians. There is a high level of system failures in the field, which could potentially lead to a belief amongst rural householders that PV systems are unreliable.
- The existing market is mainly for components (modules, batteries, lamps) for small PV. The user either assembles the system or procures the services of an installation technician separately. Many components are sold without warranty, and without guidance on the use of regulators or on load sizing. This has led to significant number of poor quality systems being installed.
- No end-user finance and most financial institutions are unfamiliar with PV. The Kenya based PV companies are relatively small players with a limited ability to absorb, use effectively or co-finance PVMTI / SDC funds in large amounts. The companies also have little experience of credit and finance and are relatively unimaginative with respect to financing mechanisms and deal flows. PV companies are inexperienced with corporate finance because rates are 22-35 % or higher, if at all available. While PV companies are inexperienced there is enough enthusiasm to show that they would readily learn the system if rates where within their reach. Hire Purchase companies may finance about 2 000 systems per year often using a salary check off.
- Lack of consumer awareness of what is a good PV system.
- Companies are not investing in training partly because trained personnel are tending to establish their own businesses creating more competition and reducing company margins.
- Lack of commercial and management skills within the PV enterprises coupled with limited resources and lack of affordable financing available to the PV enterprises.

There are no manufacturers of PV modules in Kenya and it is unlikely that there will be in the near or medium term. There are 15 principal system integrators and importers, 2 principal manufacturers of batteries and 9 main lamp manufacturers.

The majority of PV distributors sell components directly to end users often without advice on system design or installation. The final outlet for PV components is usually a trader who provides no warranty and who is not qualified or experienced to provide installation and sizing advice. This is believed to have a serious effect on quality of installation as well as system sizing.

Therefore the PVMTI programme aims to address the market barriers and does not develop PV manufacturing capacity but focuses on:

a) Ensuring quality of systems design and installation, by increasing technical resources and competence through training;

b) Establishing marketing and customer service infrastructures;

c) Providing managerial and commercial training for company managers;

d) Securing the involvement of financial institutions in delivering appropriate credit schemes.

- **Morocco**

In 1997, approximately half of Morocco has been electrified with a grid that is largely reliable. However only 16 % of this electrification is in rural sectors. Building on a sequence of rural electrification programmes, the government is committed to electrifying most of the remainder of the country (1.6 million households) by 2010, and has indicated that approximately 5 % of those households should be electrified using off-grid solar and wind technologies. The annual PV market was 1.0 MWp/year in 1997.

Responsibility for implementation of the rural electrification programme lies with the state owned utility, ONE; who intend to structure funding as follows: ONE will contribute 35 % in cash (from a 2 % levy on existing grid customers); ONE will provide a further 20 % in kind; the local community will add 20 %, provided as a loan from the state-owned municipal finance company, and recovered from local sales taxes; and the user will be asked to provide the remaining 25 %.

The PV industry in Morocco is still developing. There is substantial interest in the sector by both the government and the private sector. The market is quite disorganised and market analysis for the high potential market sectors has not been extensive. However there is a significant potential for PV in Morocco and substantial awareness in rural sectors, which are the primary target areas.

The key characteristics of the Morocco PV market are:

- Undeveloped availability of financing and financing mechanisms to implement rural programmes
- An immature indigenous industry, which is ill equipped to provide reliable product and support that product without dependence on foreign markets
- Government initiated rural electrical supply schemes with PV without adequate service support and supplier/consumer commitment which has led to the perception that electricity from PV is a second quality option
- An initial experience focused toward battery charging stations, which emerged from traditional habits, rather than stand alone SHS, which offers higher quality, and lower cost electricity to the consumer if credit mechanisms are in place.
- Difficulties encountered by private sector ESCO's in securing funding. These difficulties centre on lack of confidence by finance organisations in market development and the viability of establishing business services
- An undefined clear interface between the ONE managed rural electrification scheme and schemes set in place by private entrepreneurs operating outside of the ONE framework.
- Some 30 organisations have been identified as being involved in manufacture, systems integration, supply and/or distribution of PV equipment or BOS. There are six suppliers of modules from international sources and one active local manufacturer of PV modules.
- The Moroccan PVMTI programme aims to address the barriers in the market through:
- Ensuring quality of systems design and installation, by increasing technical resources and competence through training;
- Establishing marketing and customer service infrastructures;
- Providing managerial and commercial training for company managers;
- Securing the involvement of financial institutions in delivering appropriate credit schemes;

- Homogenising the various PV programmes.

Project Description

Project Infrastructure and Institutional Arrangement

The project is administered by the IFC through an External Management Team (EMT). The EMT, comprising of technical and financial experts, is responsible for attracting potential investee companies, for negotiating investments on behalf of IFC and for monitoring investment performance over the life of the project. Investment decisions are made by the IFC PVMTI Investment Review Committee following recommendations by the EMT.

The EMT is headed by the PVMTI Investment Manager who reports to IFC directly. The investment manager co-ordinates the work of three full time Country Managers, who manage the investment process, with assistance from support staff and access to the resources of the EMT's local partner organisation. The Local Partner Organisations provide consulting, monitoring and other support facilities. Once the investment process is complete the Country Managers withdraw and the local partner organisation monitors the portfolio and ensures timely repayments and reporting.

Project Proposal Preparation

PVMTI's solicitation and selection approach provides a competitive element that is expected to maximise financial leverage and deliver sustainable and replicable near-commercial projects by providing successful and replicable examples of good business and technical practices.

The IFC/EMT published a Request for Proposals (RFP) in each country in September 1998. The RFP document had the same structure in all three countries, with modifications to reflect country-specific terms and conditions.

Potential investee companies were invited to submit business plans describing growth using PV products. IFC seeks to invest in companies that have potential for developing the local PV market by providing consumer finance schemes, expanding business distribution and service networks or making use of innovative marketing techniques. Projects are selected based on their strategic impact in overcoming the barriers and transforming the PV market in a manner consistent with GEF.

There are two options for fund disbursement as a priority track or a secondary track. Proposals eligible for the Priority Track had to be received by the EMT Country Manager three months after RFP publication. Those proposals meeting an absolute standard were evaluated competitively. After initial pre-selection of proposals, the EMT negotiated the final terms and conditions of each investment with potential investees. During this period, PVMTI funds were held in reserve; should negotiations have been abandoned, the funds would have become available to other companies bidding. On satisfactory conclusion of negotiations, the EMT recommended that the IFC authorise the investment for proposals with the highest evaluation scores and permit disbursement of funds through the PVMTI Banking Associate.

Proposals received after the closing date for Priority Track investments enter the Secondary Track. The Secondary Track will stay open until all PVMTI funds have been disbursed up to a maximum of three years from the publication of the initial RFP. Proposals rejected in either the Priority Track or the Secondary Track may be resubmitted in the Secondary Track (provided that the reason for rejection has been mitigated).

Project Financing

There is a minimum and maximum size for PVMTI investment into a single entity which vary in each country and are summarised below. To ensure adequate commitment from proposers, a minimum level of co-finance is required before a PVMTI investment can be authorised. The minima are greater in India where many PV companies have strong balance sheets and financial institutions are relatively sophisticated.

Investment Terms				
Country	*Minimum Investment*	*Maximum Investment*	*Minimum Leverage*	*Expected Leverage*
India	1 million USD	5 million USD	3:1	3:1
Kenya	0.5 million USD	2 million USD	1:1	1:1
Morocco	0.5 million USD	2 million USD	1:1	2:1

Due diligence and monitoring conducted on investee companies are fully in line with commercial norms. However, all investments incorporate a degree of concession with precise terms to be negotiated with individual sponsors.

Investments can be as a debt investment or as an equity investment. For a debt investment, the proposer specifies the term of loan, the moratorium period, the interest rate, the seniority of the loan, and the security offered[10]. From the forecasted cash-flows, the proposer must also demonstrate the average and minimum debt service coverage ratio (and sensitivity to key risk factors) over the lifetime of the loan. Debt finance may be tax efficient but involves a fixed repayment schedule which if the business struggles could cause problems. In addition, USD loans mean that the sponsors face some foreign exchange risk.

For an equity investment, the proposer should indicate the status of the equity investment (preference share/ordinary share) and the target internal rate of return for the investment (net of all taxes). In addition, the proposer should describe an exit strategy for the investment within the (ten-year) lifetime of PVMTI. It is normally for a longer period than debt with no fixed repayment date, however equity dilutes returns to sponsors and may involve costly legal documentation.

Either type of instrument may be used to capitalise “guarantee facilities” for end-user finance schemes. PVMTI funds will not be used to provide a sole source of funds for such schemes

An important aspect of PVMTI is that the majority of the funds are invested as concessional finance to be repaid by the end of December 2007. Up to 10 % of funds disbursed to an investee company may be registered as a grant to be used for specific purposes such as training or technical certification.

Additional co-financing of 60-90 million USD by project sponsors and other sources (including commercial banks) is expected to result in total project investment of 85 million USD to 115 million USD by the end of the programme.

Project Implementation

- **India**

Project Implementation in India

PVMTI India has received 29 proposals to date from different industry segments. The proposals included new credit schemes, new uses of PV technology, creative financing mechanisms and entry to new geographical markets. Significant co-financing has been pledged from promoters, the Indian Renewable Energy Development Agency (IREDA), commercial partners and other consortium partners.

The EMT conducted an accreditation study for PV equipment certification in an effort to contribute to improved service quality delivery and standards.

[10] By asking for security, the IFC/EMA will (1) instil a degree of market discipline into investee companies, and (2) create a disincentive to misappropriation of funds.

The first PVMTI investment was approved by IFC in September 1999, a fund of 2.2 million USD to Shri Shakti Alternative Energy Ltd. (SSAEL). The funds comprise equity investment (26 % of the company), a loan and a small grant. The total project cost is 10.18 million USD. SSAEL is building a network of over 300 Energy Stores in South India, Orissa and major towns in northern India to sell consumer products based on PV and other alternative energy technologies.

Shri Shakti Alternative Energy Limited (SSAEL) is the newest enterprise of the Shri Shakri Group. The principal company in the group is India's largest private sector marketer of liquid petroleum gas (LPG) through a network of 350 dealers. Each dealer is a franchisee who secures a franchise by providing well located retail space in an urban area and paying a small deposit. The franchisee then sells bottled gas. By upgrading and extending a portion of the existing bottled gas network the company will have access to both a management network and a base of energy customers.

SSAEL aims to increase significantly the consumer adoption of high quality PV products. The stores are not tied to any manufacturer and so can source their products from both Indian and international suppliers. The company has established strict quality assurance guidelines and staff will be trained in sales, installation and servicing of the product range including educating the customer in preventative maintenance.

To improve the affordability of its products, SSAEL also intends to extend its consumer finance packages from short–term credit (a few months) to medium term credit (2-4 years) and hire purchase. The company is in discussions with financial institutions able to provide this service.

Three energy stores, owned by SSAEL, are in operation in Kakinda, Hyderabad and Bangalore using a loan from IREDA to provide the required financing. Additional stores are planned for Chennai and Delhi.

The second PVMTI investment was approved in December 1999. This was a 2.35 million USD investment to SREI International Finance Ltd provided as a loan and a grant, as well as a partial guarantee for default on consumer loans of up to 1.15 million USD. The total project cost is 12.5 million USD. SREI International Finance Ltd will develop a retail and service network and will provide consumer finance for the sale of photovoltaic (PV) solar home systems and portable PV power packs in West Bengal, India.

SREI International Finance Ltd is a Non-Banking Finance Institution (NBFI) providing leasing and hire-purchase finance for construction and industrial equipment, as well as vehicles in India. Besides individual investors, SREI International Finance Ltd is currently owned by the directors and their relatives, corporate investors, government-sponsored financial institutions and mutual funds, IFC, and bilateral institutions. SREI International Finance Ltd will team up with the Ramakrishna Mission ("RKM") a non-profit organisation located in Narendrapur, West Bengal, and Tata BP solar, one of India's leading suppliers of PV systems. The consortium will employ standard approaches to consumer finance to provide solar loans, will adopt well-tested customer-oriented marketing and sales techniques; and will exclusively supply high-quality products. Established in 1955, RKM already operates an extended network with access to rural consumers and has facilitated the sale and financing of over 2000 SHS under several donor-funded programmes.

The third proposal, which has been recommended for approval, is a 4 million USD investment for Shell Renewables India (SRI). SRI intends to open a network of Shell Solar Centres in Southern India. SRI will work together with financial intermediaries, who are to offer consumer finance. The entrance of Shell in the Indian PV market will further enhance the profile of solar technology and ensure the presence of an additional quality supplier of PV systems.

In addition PVMTI India is considering a number of other innovative proposals including solar powered cash machine for banks, internet centres, phone booths, PV equipment for illuminating advertisements and PV powered pumping, treatment and packaging stations for drinking water.

The entire PVMTI 15 million USD is likely to be committed and with the leverage of another 45 million USD the PV industry in India should benefit substantially.

Project Impact

The implementation of the PVMTI projects will see the following happening in the Indian PV market:

- Availability of good quality projects;
- Customer driven high quality service delivery;
- Better availability of trained personnel;
- Introduction and wide availability of affordable financing mechanisms;
- Energy of strong new business players;
- Innovative use of PV;
- Reduction in prices of modules and BOS components with the increased volume.

- **Kenya**

PVMTI Kenya has received 23 proposals to date for investment from a range of commercial companies and financial institutions. The proposals all involved the consumer as the ultimate owner of the PV system, incorporated a consumer credit scheme and involved multiple commercial partners.

Quality issues and technical guidelines have been provided to investee companies through a workshop on certification of PV training activities.

The first PVMTI approval in June 2000 was a 1 million USD loan and grant to the Kenya Commercial Bank Ltd (KCB) to enable them to provide consumer loans for the purchase of fully installed and maintained Solar Home Systems (SHS). Technical support in terms of supply, installation and maintenance is provided by Solagen Ltd, a local distributor for BP Solar.

The second PVMTI investment was approved in August 2000 for a 600 000 USD loan for the Muramati Tea Growers SACCO who provide loans to their members for the purchase of SHS. Muramati is a Savings and Credit Cooperative Society (SACCO) whose membership is mainly drawn from the tea farmers in the central part of Kenya. The technical partner for the scheme is ASP Ltd who source PV systems/components from a variety of recognised suppliers of PV modules and balance of system components.

A third project recommended for approval is a further 1 million USD loan and grant to KCB which is to on-lend to SACCOs, who will provide loans to their members for the purchase of SHS. Negotiations are underway on a number of other projects.

Success of PVMTI in Kenya lies in providing finance to commercial banks, SACCOs and other financial intermediaries who can provide consumer loans for SHS to a wide customer base in rural areas of Kenya.

- **Morocco**

PVMTI Morocco has received 11 proposals for investment to date and has short-listed three proposals for early evaluation. The proposals are mainly targeted towards large-scale installation of SHS for rural electrification.

The EMT has reviewed the PV certification programme and testing facilities as a potential resource for PVMTI Morocco.

In villages where ONE, the national utility, does not plan to extend the grid in the medium term (10 years) it has agreed to pay 300 USD for each SHS installed by selected private firms as part of PERG, the national rural electrification programme. At present PV companies are not well enough established in Morocco to be able to deliver low cost long service SHS to rural dwellers for a profit. Their financial requirements are high during the first few years whilst installing systems and finance through normal commercial routes is scarce. Therefore PVMTI funds are likely to be provided as subordinated debt or a guarantee fund to financial institutions working with SHS retail companies.

ONE launched a tender in August 2000 to select companies that will benefit from its fund in installing and managing SHS. The EMT is working with the industry association and with ONE to define the new fee-for-service approach. It is also ensuring that the potential candidates are addressing: the quality of installation; training of technicians; long term maintenance including replacement of equipment; and battery recovery and recycling.

Lessons Learned and Success Factors

The success of PVMTI to date can be judged by the following criteria.

Sponsors – a number of strong new entrants have joined the market thus increasing competition in the countries.

Profitability – several projects are likely to be commercially viable after only one round of concessional financing.

Financing – third parties (e.g. banks) are committing funds to PV deals in the three countries.

A mid-term programme review will be performed in 2003 and a final programme review in 2008. These reviews will include an evaluation of the financial performance of the investment portfolio and the strategic gains of PVMTI in terms of developing markets and accelerating dissemination of PV.

There are several key themes that underpin the success of the programme to date:

- **Country unique business environment** – each country is unique and one solution is not applicable to all.
- **Flexible investment** – flexible PVMTI investment terms facilitate optimal structuring of projects.
- **Good management** – a strong and experienced management team is vital component of the business plan.

2.14 The Take off of the African Commercial PV Sector

Case study prepared by FP van der Vleuten, Free Energy Europe, NLD

Introduction

Several countries in Africa have developed PV sectors that supply solar home systems on a strictly commercial basis. While some of the *constructed* market models of multilateral and bilateral donors have been not been successful, the African private sector has been very effective, including photovoltaics as part of their business activities and have already reached over 250 000 households.

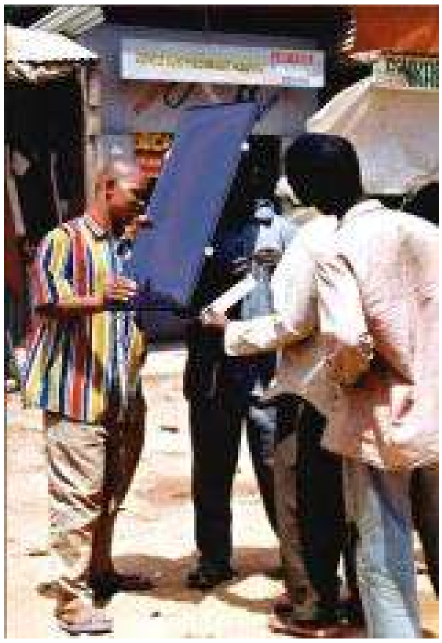


Figure 2. *Selling a system in Bamako*

West Africa

A good example of a business within the African private sector is that of Monsieur Doucoure from Mali, who has business activities in several West-African countries. Doucoure trades in electronic equipment and accidentally came across photovoltaics. "I was importing electrical appliances such as radios and televisions from the Far East, when I met a supplier of solar panels. I thought of my mother in the village and decided to try the panel to give her electrical lights in her house."

Doucoure saw that it worked and that it attracted substantial interest from other villagers. He therefore decided to start importing. He started offering two products: A 50Wp panel for richer clients who wanted a fully-fledged system and a 12Wp panel for basic systems for lower income households.

Doucoure appointed dealers in the regions where he expected the main markets to be: in the market part of the capital, in the region of the cotton co-operatives and near the border with neighbouring countries. The customers recognised the products and the market started picking up fast. In the first year he sold about 50 systems. After five years he had increased his market to a level of several thousand systems per year. Out of every 5 systems sold about three or four are 12Wp panels with a simple LED charge indicator, and one or two are 50Wp panels, complete with a charge regulator and lights.

Visiting the informal market in the capital of Bamako, many street traders know about solar energy and can advise on it. An informal sector trader in Indonesian black and white televisions said, "if you don't have electricity from the grid, the best thing is to use these televisions with a car battery that is charged through a solar panel. If you just have one wife, you can use one of the small black panels to power the TV and one light. If you have several wives and want to illuminate all their rooms, it will be better to buy a blue panel. More power."

Figure 3. ***Abdulla's solar shop in Nairobi***

East Africa

In Kenya, in the early 1990s, the three Abdulla brothers were involved in selling electrical appliances, such as televisions and refrigerators. They had a similar idea as Monsieur Doucoure from Mali and started importing 12 Wp panels from France and 50 Wp panels from Japan.

They noticed that the market was very receptive, especially to the 12Wp panels. "About four in every five customers take a 12Wp panel, that they connect directly to the battery. They use it primarily to be able to watch television. And light, of course, but the television gives light as well."

A typical market model that developed in Kenya is to buy a solar system in phases. First people buy a battery, then a television. Next cropping season they may then buy a solar panel. Each time the capital outlay is between 40 and 60 USD, about the maximum they can afford after a good crop. "We also sell charge regulators and solar lights. However, many clients for the 12W panels have found out that for the price of a charge regulator, they could almost buy an additional panel. What would you do?"

The market in Kenya has developed into a model market, where between 15 000 and 25 000 systems are being sold each year. Despite initial doubts regarding the technical quality of the systems, evaluations have indicated that the majority (80 %) of the systems are working well.

A much-debated aspect is the quality level in the commercial market. It appears that to some extent the market has developed its own quality control system. A trader on Accra Road in Nairobi says, "There was a brand of 12 Wp panels on the market that had a very high failure rate. Because the investment of 60 USD to buy a solar panel is quite high for the customers, they ask around to find out what they should best buy. Within a month after the massive failures started, people started rejecting this failing brand and opted massively in favour of another brand that had demonstrated good quality in the field."

Morocco

Another market that is well developed is that of Morocco. Again a significant private sector has developed, especially for the supply of the smaller 12 Wp panels. These panels are used in small 12 or 24 Watt systems that seem to fit very well with the demands and affordability of the end-user. Over a period of a few years the market developed to a size of over 10,000 systems per year.

However, then a project intervention occurred. A dealer in Casablanca quotes: "The government had seen that PV was a solution for the energy problem of low income groups in unelectrified areas in our cities as well as in the rural areas. They decided to go for a massive, highly subsidised dissemination of larger 50Wp PV systems. From the point when the first plans were published, our market came to a virtual standstill. It has now been like that for almost two years, while everybody is waiting for the government project to really take off. It is unclear how this project will perform."

Figure 4. A dealer in Casablanca

Lessons Learned and Success Factors

The commercial markets described above do not figure prominently in published statistics. This probably comes from the fact that technical thinking has dominated the international PV sector, and evaluations tend to be made in Watt-peaks sold instead of number of systems sold or number of households served.

When analysing the number of households served, the African commercial markets have been very successful in a number of African countries. When support from, for instance, international donors is available to increase access by rural households to sustainable electricity, the main priority areas for support should be:

- In existing markets, such as those mentioned above, how can the development of the market infrastructure be supported in a sustainable way? A high priority would be to strengthen the knowledge infrastructure in the market, allowing retailers and end-users to make better-informed choices as to the value for money of their systems.
- There are many countries in which the commercial infrastructure has not developed at all. When looking at how to develop a market infrastructure to serve the dispersed peri-urban and rural households, the example of the successful African commercial PV markets should be taken into account. Basic support could then be a combined effort of capacity building, demonstration, promotion, and (small) business development. The core focus of this effort should then not be on centrally financed system-based projects (distorting the market and reorienting companies on these projects), but rather on identifying and exploiting commercially viable opportunities.

2.15 The World Bank Energy Services Delivery Project: Credit Program and Capacity Building - Solar Home Systems

Case study prepared by G. Stapleton, GSES, Australia

Introduction

The Government of Sri Lanka places high priority on rural electrification. It envisions rapid expansion of electricity access to enhance rural economic and social development. The aim is 75 percent electrification by the year 2007. At the request of the Government of Sri Lanka, the World Bank and the Global Environment Facility (GEF) agreed to provide funding assistance for an Energy Services Delivery Project in March 1997. The project commenced on 22 July 1997 and was completed in December 2002.

Aim and Objectives

The project comprised three components:

1. An ESD Credit Programme;

2. A Pilot Wind Farm;

3. Capacity Building to support the Ceylon Electricity Boards Pre-electrification Unit and its demand side management unit.

The credit programme aimed at providing medium and long term financing to private project developers, NGO's and co-operatives for off-grid electrification such as solar home systems (SHS) and village hydro schemes, grid connected mini-hydro plants and other renewable energy investments.

This case study focuses exclusively on the Solar Home System component of this program. The long-term objectives of the ESD program with respect to SHS were to:

- Incorporate environmentally sustainable renewable energy objectives within the policy framework for pre-grid rural electrification (Solar Home Systems);
- Achieve acceptance by consumers, project developers and financial institutions of the viability of off-grid renewable energy systems for electricity generation and delivery.

Project Background

Sri Lankan Solar Home System Market Prior to July 1997

41% of households in Sri Lanka are not connected to the grid. This represents approximately 2.0 million houses, which is a large potential market for SHS. The majority of households use kerosene for their lighting, though some do use regular automotive batteries for lighting and TV which are recharged in the nearest village that is connected to the grid.

Throughout the 1980's and early 1990's there were a number of government initiatives and private industry involvement in the PV industry. In 1980 the Sri Lankan government became involved with solar PV for rural domestic use through forming the Ceylon Electricity Board's, Energy Unit. The CEB Energy unit imported a few hundred solar modules made kits using local lamps and sold from their head office in Colombo, they did no major awareness raising activities.

In the 1980's there was three private companies active in selling SHS. These included Vidya Silpa (formed 1981), Sunpower Systems Limited (formed 1987) and Power and Sun Limited (formed 1986). In addition BP Solar Australia opened an office to implement Australian funded projects where Sunpower were their agents. These projects included 1000 homes in Pansiyagama (North Western Province) and 74 large systems for hospitals and water pumping in the Uva Province infrastructure project. Unfortunately the 1000 home project in Pansiyagama was regarded as a failure as the credit scheme, similar to the fee for service model, failed when repayment dropped below 50%. Factors that contributed to this low repayment figure were the inexperience of the government agency which handled the credit scheme and the technical complexity and unreliability of the central inverter based solar home system.

In 1988 Power and Sun commenced manufacture and sales of PV modules under the SUNTEC brand name. The company also manufactured modules on behalf of BP Solar for the Australian aid funded projects. In addition the company established technically trained agents and dealers within the rural areas to promote SHS systems. In 1991 the company changed its name to Solar Power and Light company. The company stopped manufacturing in 1996 and then became agents for Solarex in Australia. In 1991 the company also lobbied the Sri Lanka government to seek aid funding for solar home systems.

In 1991 a NGO called Solanka was formed using Seed funding from the Solar Electric Light Fund (SELF). This NGO focussed on developing solar co-operatives in the villages. In time this NGO became a company called RESCO Asia Ltd.

At the time that the World Bank programme commenced there was only three companies operating the SHS market. These were Solar Power & Light Company, RESCO and Alpha Thermal a local manufacturer of solar water heaters that were also expanding into the SHS market.

All these companies were relatively small and had maximum staff numbers of approximately 20 to 30 with agents/distributors working on commission in the rural areas. The maximum sales of any one company each month were approximately 30 systems.

Project Description

Initial aim and Operation of ESD Credit Program

The initial target was for the installation of 30,000 solar home systems. US$5 million dollars was allocated for the pre-electrification by solar home systems or by village hydro systems. These funds were made available to Participating Credit Institutions (PCI's) to on-lend to private enterprises, NGO's and co-operatives to provide the systems to villages.

In addition to the available micro credit there was a GEF grant component of US$100 per PV SHS with a module rating not less than 30W.

GEF funds were also available for the following support activities:

- Off-grid project promotion. The administration unit (AU) had funds to undertake promotions that would increase awareness amongst potential customers;
- Solar Home System design verification. The PCI's could hire consultants to verify SHS designs were in accordance with IDA-approved specifications and that the systems were installed properly;
- Consumer Education and Protection Facility. This will allow the AU to investigate complaints by consumers against dealers.

Project at Mid-Term Review February 2000

At the mid-term review the target was that 6000 SHS would have been installed the actual figure was only 723. The mid-term review found that the poor performance of the SHS component of the credit programme was a result of a number of technical and implementation issues. In summary these were:

- SHS sub loans were too small for the typical PCI's to justify the costs involved in loan processing. Hence there had been no active promotion by the PCI's to encourage the uptake of any SHS loans. The PCI's were not experienced in dealing with small rural borrowers and therefore viewed them as high risk. Therefore they were not using the money that was available;
- The SHS companies were also not experienced at being "banks". In general they did not want to get involved with obtaining the funds from the PCI's and be involved with providing loans directly to the system owners. If companies did look at this option they found that the cost involved in securing the loans and processing micro-loans was too high. Also at the time the solar companies did not have a vast dealer network in the rural regions to promote loans nor easily service the loan applications.

Without the infrastructure to provide loans to the potential system owners in the rural areas, the potential owners were unable to obtain affordable finance to meet the upfront capital costs of a SHS. The mid-term report also found that the villages had limited awareness of the SHS option and also had incorrect perceptions on the reliability of SHS.

The recommendations from this review were that the SHS companies should focus on promotion and selling the systems and micro-finance institutions should be encouraged to become involved in the project.

SEEDS and SHELL Enter The Market

If no "micro finance" based PCI's entered the market then the results in the second half of the program would probably be similar to that of the first half. Fortunately the solar industry was actively working to make the program a success and grow the market.

Just prior to the mid-term review, two events occurred, that through their combination contributed to the program becoming successful.

1. Solar Power & Light (SPLC) signed an agreement with the Sarvodaya Economic Enterprises Development Services (commonly known as SEEDS) where SEEDS would provide credit for all sales done by SPLC. The recommendations from the mid-term review made it easier for SEEDS to become a PCI and therefore have access to the funds available in the ESD program.

2. The Directors of SPLC actively sought out Shell Renewables and arranged for a takeover. This provided capital investment of over USD 2.0 Million to develop the sales, service and product delivery infrastructure around the Island. The company went from staff of 20(pre-Shell) to almost 400 in two years and created the ability to reach most of the remote SHS customers around the Island. This operation was supported by the establishment of 16 solar centres around the Island.

Impact of the Project

The success of the project can be seen in the growth in systems installed. The cumulative number of systems installed has been:

- March 1999 : 122 Systems
- March 2000 : 711 Systems
- March 2001 : 3206 Systems
- June 2002 : 18,619 Systems.

Sales in late 2002 were averaging 1000 –1600 systems per month.

The Industry at end of the Project

By December 2002 there were 4 companies active in the industry with interest by 2 other companies to enter the industry.

During the project Solar Power & Light had been purchased by Shell Renewables to form Shell Renewables Lanka Ltd. Management was retained and building on the success of sales growth stimulated by SEEDS, the company proceeded to open up 16 regional outlets / service centres.

RESCO Asia became part of the SELCO network and also actively opened up remote centres.

One of the largest private companies in Sri Lanka, Access International entered the industry and formed Access Solar.

While Alpha Thermal stayed active in the SHS industry.

By June 2002 there were other 50 solar centres located in rural areas. The three larger companies (Shell, Access and Selco) were reporting sales of 400 to 800 per month while Alpha Thermal were averaging 100 to 120 per month. The number of people working in the industry is over 1000.

Solar Industry Association- Sri Lanka

The project had a side benefit in that it encouraged the small number of industry players to work together for the good of the whole industry. In so doing they created the Solar Industry Association of Sri Lanka (SIA-SL) which obtained financial support from the ESD.

The SIA is a non-profit organisation that has two full time staff. It acts as a catalyst between the industry, the Government and the World Bank. It has worked actively in helping with all promotional work of the ESD and solar in general. This has been undertaken by working closely with the Sri Lankan Business Development Centre to promote solar at the grass roots level.

The SIA has coordinated the capacity building within the industry through technician training courses. Capacity building activities of the project are described in more detail below.

Capacity Building - Training of Technicians

At the commencement of the ESD program a one-off technician training course was conducted. However, the SIA wanted a more sustainable programme.

In February 2000, Global Sustainable Energy Solutions Pty LTD (GSES) from Australia conducted a “Train the Trainers” course. The QUA-P programme of the ASTAE unit of the World Bank funded the course.

The trainers were trained to teach a Solar Home System course that was based on the 5 day certification course conducted in Australia. The course content also followed the standard task analysis for Solar Home Systems developed by the Institute for Sustainable Power (ISP). The course manual had been translated into Sinhalese and a Trainers manual had been developed to help the trainers conduct the course in the future.

The aim of the course was to have 3 to 4 senior technicians from each of the 4 companies being trained to conduct all future technician-training courses for their respective companies. Though the technicians were competent to conduct training and some companies conducted in-house training the scheme did have in-built problems. Since the companies expanded rapidly the senior technicians were needed to help with the expansion, they did not have the time to conduct 5-day training courses.

The SIA then proposed that they hire a trainer who would conduct all training of technicians on behalf of all companies. The Administrative Unit of the ESD accepted this proposal. A trainer was selected and GSES obtained funding from AUSaid to fly the trainer to Australia to attend a training course and also study how the Australian Solar Industry Association conducted their certification program for technicians.

GSES and the SIA thought that it was very important that the Sri Lanka developed its own capacity for conducting their own training courses and not rely on overseas experts.

Since June 2001 the SIA trainer with a team of two co-trainers has conducted 20 training courses and trained over 400 technicians. Two of these were conducted for staff of SEEDS who were trained in the basics of PV and also maintenance and trouble shooting. The SEEDS staff are those who collect the loan repayments from the villages. These staff are trained to help customers who might have a problem with their system.

In addition to the SHS courses, GSES has conducted three advanced technician-training courses. These have been conducted for the senior technicians from each company and have covered the following applications:

- Solar Water Pumping;
- Grid Connected Solar Systems;
- Large Stand alone systems using AC inverter and genset back-up.

Lessons Learnt and Success Factors

The industry generally agree that the main reason for this rapid growth in sales of systems was the introduction of the micro-finance institution SEEDS as a PCI. They have a vast rural network, which enabled that institution to reach many villages and therefore potential system owners in the remote regions. SEEDS was active in promoting micro-finance for SHS.

Another contributing factor to the success of the project was the support of SHS given by some Government agencies. In particular the Uva Provincial Council (UPC) had accepted that grid connection in that province was expensive and will take many years to complete. The UPC therefore launched a programme that promotes the use of SHS with a grant of Rs 10,000 (approx U$100) per system. This scheme resulted in 6000 homes in the Uva province purchasing a SHS and the province contributed a full 50% of the market in 2001.

Lastly, local capacity must be developed to allow for in country training of technicians. The capacity building activities undertaken during the programme contributed to creating a local technical capacity to support the development of solar PV in Sri Lanka. Capacity building and in country training actions should continue to further support the development of the PV sector.

The Future

The ESD program was completed in December 2002 but it has been followed by the Renewable Energy for Rural Economic Development Programme (RERED). This program will continue the support of micro-financing SHS though the GEF grant will not be as generous.

The Report by International Resources Group in October 2002 (WB Sri Lanka Energy Services Delivery Project: Impact Assessment and Lessons Learned) stated that more micro-finance institutions like SEEDS will need to become PCI's For the SHS industry to maintain growth as seen in the previous two years. The number of sales occurring at the moment had stretched SEEDS to their existing current capacity. Fortunately in 2002 the Sanasa Development Bank and local leasing companies have become PCI's and joined the programme.

The SIA will continue but without funding from the World Bank program. They plan to be self-supporting through their members.

The training will continue but it is expected that the training will be conducted on a fee for service basis. GSES will continue to work with the SIA to help in developing a certification program for the technicians to ensure those trained are installing systems correctly and are undertaking some on-going training

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2.16 Rural PV Electrification through Energy Service Companies in Zambia

Case study prepared by A. Arvidson, SEI, Sweden

Introduction

This case study highlights some of the experiences from a pilot project (the “PVESCOs” project) providing energy services to 400 clients in the Eastern Province of Zambia through three Energy Service Companies using Solar Home Systems. The experiences described relate to institutional and financial infrastructure, quality control, capacity building and impacts on end-users from paying for solar electric services.

Aim and Objective

The main objective of the PVESCOs project is to identify the modalities needed and the specific issues associated with the provision of solar electric services in Zambia. The ambition is that the project experience can be used to design the institutional framework necessary for incorporating this mechanism in the national rural electrification strategy of Zambia.

Project Background

The Zambian Government in its National Energy Policy seeks to promote increased access to modern forms of energy, especially electricity, for the majority of the population. To increase the access to electricity of the rural population, a rural electrification programme was established in 1995, funded by a 3% electrification levy charged on all electricity consumers. Despite the introduction of the levy, not much progress has been made in increasing the levels of rural electrification mainly due to high costs of grid extension and low load demands not making it justifiable to extend the grid. This situation has motivated the Zambian Government to explore other approaches to reaching rural areas with electricity services other than through grid extension. The government thus decided to initiate the “PVESCOs” project in the Eastern Province of Zambia.

The project was initiated in June 1998 and is implemented by the Government of the Republic of Zambia through the Department of Energy (DoE) under the Ministry of Energy and Water Development, with technical assistance from the Stockholm Environment Institute in Sweden.

The approach is based on an Energy Service Company (ESCO) model where ESCOs provide energy services through solar PV equipment. The ESCO is the owner of a number of household size Solar Home Systems (SHS), which are installed at the premises of clients. The ESCO ensures the continued operation of the SHS by regularly servicing and maintaining the equipment. In return the clients pay a service fee.

Summary of project experience

The Zambia PV-ESCO project has been running since 1998. The project has supported the formation and operation of three ESCOs, located around the towns of Nyimba, Lundazi and Chipata and as of October 2002, these three ESCOs serve a total of 400 clients. NESCO in Nyimba has 100 clients and the other two in Chipata, CHESCO and LESCO in Lundazi each have 150 clients.

Table 2 summarises the main activities and events in the project since it started in 1998.

Date	Activity
June 1998	Project launching at National stakeholders' workshop on renewable energy in Lusaka:
July 1998	Socio-economic field survey of project areas
October 1998	Information campaign in Eastern Province on benefits and limitations of PV and the ESCOs concept
October 1998	Field surveys and identification of potential ESCOs
November 1998	Business discussions with potential ESCOs
March 1999	Screening and selection of companies to become ESCOs
March 1999	Business management training of ESCO management staff
June 1999	Public call for tenders for 1st batch of 100 SHSs
June 1999	Technical training for ESCO technical staff
September 1999	1st batch of 100 SHSs ordered from Electric Maintenance Lusaka, Ltd.
December 1999	12 demo SHSs installed (8 in Nyimba, 2 in Chipata and 2 in Lundazi)
May 2000	Installation of first 100 SHSs started in Nyimba
July 2000	Public call for tenders for 2nd and 3rd batch for installation in Lundazi and Chipata, respectively
December 2000	100 SHS installed with NESCO clients
February 2001	Contract signed for the supply and installation of 150 Solar Home Systems (SHSs) with CHESCO clients
March 2001	Contract signed for the supply and installation of 150 Solar Home Systems (SHSs) with LESCO clients
October 2001	300 SHS in Lundazi and Chipata installed and inspected
October 2002	Ministry of Energy and Water Development host national stakeholder workshop presenting a proposed strategy for expanding the ESCO mechanism in Zambia
October 2002	Credit repayment agreement discussed with all ESCOs and agreed on with NESCO
January 2003	Two systems stolen from clients to LESCO
February 2003	CHESCO experiencing problems with a number of batteries

Table 2 Main events in the course of the project

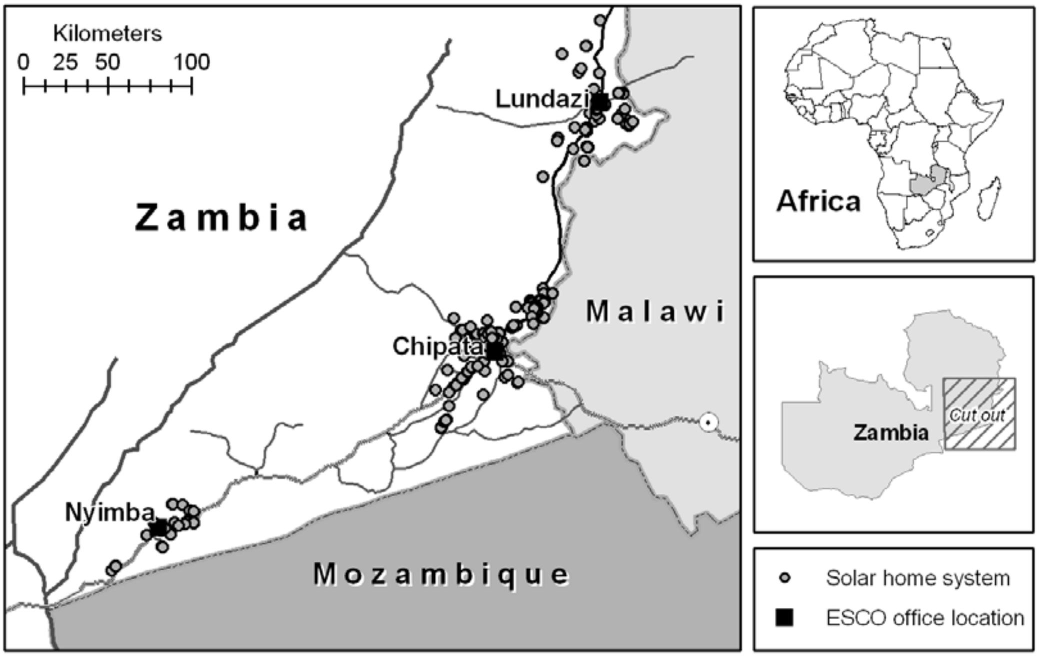

Figure 1. Map showing location of solar systems in Eastern Province, Zambia, Africa

Some of the achievements and experiences of the project are:

- Three ESCOs have been established in rural areas. Each ESCO makes a small profit, however, the ESCOs have not yet started repayment of the capital cost of the PV systems.
- 400 clients (about 2 400 people) are paying for the possibility to have light and to be able to play a radio or VCR. The current service fee (November 2002) ranges from ZMK 30 000 to 45 000 (7.5 to 11 USD) per month per system.
- The project targets the better off in the rural setting. Most of the clients have one or more members formally employed. The access to electricity services has meant improvements and new possibilities in daily life, such as doing domestic work at night, reading and studying as well as using entertainment equipment such as a TV and video. Rural access to solar power means getting opportunities to do things that are only accessible for people in urban areas.
- Surveys covering the clients of the ESCOs and their neighbours reveal that clients quote the quality of light as one of the major advantages with the SHS, especially that it has provided children with the opportunity to study after dark. While PV is not frequently used for productive purposes in the households, it has definitely served to boost businesses in shops, bars, restaurants and motels. Many of these enterprises say they have extended their business hours.
- Living conditions for civil servants, such as teachers, service men and police in remote areas have become more attractive.
- The payment morale among clients is reasonably high, and although there can be delays in payments, about 95% of the clients eventually pay. The first ESCO has taken a proactive approach to long-term defaulters, and for those not paying after several months, the system is removed and placed with another client. Thus, 68 of 100 systems installed with NESCO clients are in original installations and 32 systems have been moved at least once and installed with new clients.

- Surveys also reveal that clients are willing to pay more for solar electricity than they were previously paying for kerosene, candles and batteries. This is in spite of the fact that they do not get more hours of light. However, the light is of a higher quality.
- There is great interest among other rural households to be able to start using the same mechanism. Thus each existing ESCO has a waiting list of 200 – 300 applicants.
- Some of the ESCOs have entered into maintenance contracts with public institutions (health clinics) based in the Eastern Province, which have received PV installations through previous donor projects.
- 10 technicians and 10 administrative staff have been trained and employed by the three ESCOs (some part time).
- Some clients over-use the systems, especially businesses. In Nyimba, 43 batteries out of 100 have been replaced by NESCO. 12 in the first year, 12 in the second year and 19 so far during operations in the third year.
- Three PV panels have been stolen (2 in the Lundazi area and 1 in the Nyimba area) out of which one panel was retrieved. This experience is valid for the 100 systems that have been in operation for 1-2 years, and the 300 systems that have been in operation for 6-12 months.
- Some technical features (pre-payment meters in Chipata) were not fully developed at time of installation.
- There have been long waiting times to start due to long tendering procedures

Project design and development

The design and implementation of the pilot project has been quite flexible and allowed for necessary and important adjustments to be made. A flexible approach is necessary in these kinds of projects where the main objective is to learn and better understand how a sustainable approach to PV deployment can function under the specific conditions of a country like Zambia.

Financing PV

The initial project design was based on the idea of making rural entrepreneurs aware of the potential of PV, its benefits and limitations, provide them with training and a credit to purchase PV systems. With awareness about the possibility for this kind of business, adequate training to be capable of supplying the energy services, and credit provision, the assumption was that the wheels would start turning.

After assessing the situation in the financial market, the idea of providing credit through the existing commercial banks had to be abandoned. This was for three reasons:

1. The banks in Zambia have prohibitive interest rates typically in the range of 40-50%. With an inflation rate of about 20% very few investments would yield a profit to offset this interest rate.
2. Very few banks have a service network in rural areas. When the project started there were three banks present in the Eastern province, but today there is only one.
3. There was no interest from the financial institutions to take any part in the risk of the undertaking, The services offered were limited to manage funds on the behalf of a lender, and to act on clear and definite instructions.

Institutional Issues

Ownership

The Zambia experience is still a pilot project, with many of the conditions of the real world missing. The present situation is that the Government of the Republic of Zambia (GRZ) is the owner of the equipment, with the Department of Energy exercising the obligations of the owner. Thus, the ESCOs have, so far, only been performing in a lent costume. This is not a satisfactory long-term solution for the equipment in the project, let alone for the development and growth of PV use in rural areas. The ESCOs also clearly express the wish to own the equipment.

Since the commercial credit route was abandoned and the ESCOs established, the basic understanding has been that the ESCOs will eventually be the owners of the equipment and begin repayment after two years of operation. With the emerging experience from the pilot project is now possible to better understand the financial conditions under which an ESCO in Zambia can operate including what the actual costs and incomes are.

The current idea about the way forward is that the repayment period will be twenty years, and the repayment will be based on the initial purchase price, with inflation added and a small premium for administration of this mechanism. The grace period of two years, which was decided from the beginning, translates into a 10% subsidy on the capital cost immediately. In this mechanism, the ESCOs will become the owners of the systems once they sign the agreement for repayment, but they will immediately have to pledge the PV systems as collateral for paying. This is done through a system of “Ownership certificates” which are issued for each individual SHS.

The long repayment period allows the ESCOs to keep the fees at what is considered to be a reasonable level but at the same time does not require such a large capital subsidy. One consideration has been that the capital should actually be repaid and not be given away.

An agreement has been drawn up and discussed with the first ESCO to come into question for paying. It includes the above conditions, and translates into a monthly payment level in Zambian Kwatcha of 4 USD.

Payment will be performed annually, on the 31st of August each year. The reason to pay at this time is that it is after the main harvest in the region, and there is greater likelihood that clients will have caught up with their arrears. At the same time the inflation level for the previous year will be gathered from the Central Statistics Office, and applied to the capital to be paid. Upon payment, the collateral for a number of systems equal to the payment (in the present case 5 systems) will be released to the ESCO.

Battery replacement

A forced savings mechanism on the part of the ESCOs in order to cater for replacement of run down batteries was introduced in the project when the ESCOs started operation. It was estimated necessary that the ESCOs put away enough money to replace batteries every three years. Initially this fund was kept with the DoE. However, due to experience with long delays in drawing on the battery funds when necessary, these funds are now kept within each ESCOs own bank account. This allows for swifter action when batteries need to be replaced, avoiding long down times for the clients and interruptions in service fees, since the clients don’t pay when their system is not working.

Theft

Theft has not been a serious problem, although three solar panels were stolen in 2002. One of these was later recovered. This could largely be attributed to the fact that all the systems are installed in the premises of the clients, and that there is a close social control over them. Clients are also required to sign an agreement where they take responsibility for the equipment, and might be liable to very severe costs if a system is lost. One additional strategy that one ESCO has introduced is that all new installations are placed on the roof above the bedroom of the client, which could further prevent thieves from stealing panels without being noticed by the clients.

Critical size of an Energy service company

One crucial aspect of establishing an ESCO is that the company must be able to make a sufficient profit. With emerging information on the actual operating costs of an ESCO, it appears that the minimum size needed for profitable operation, including paying for the initial capital is when the company has 150-200 clients on a fee-for-service programme. The initial capital required for an ESCO with 150 SHS clients is around 150 000 USD. This is a huge amount of money for a small rural company.

Experiences show that the company must plan carefully for each step in its establishment. Company administration must be kept at a minimum – there is no point in paying high salaries for executives before there is any turnover, or employing more technicians than actually needed. At 100 clients the personnel costs take up 50% of the operational costs compared to 30% at 500 clients. Hence, for instance, the importance of chasing defaulters is less at lower numbers of clients, but becomes increasingly important. At 5% of clients in default with 100 clients, this constitutes 12% of the operational costs; whereas the same default rate at 500 clients is 21% of the operational costs.

It is also important to consider the geographical area of coverage. This has to be aligned with the means of transportation available. If the company does not have a motorized vehicle, or possibility to rent one, the area should be no larger than what is possible to reach on foot or bicycle. Extending beyond that will mean a hike in the costs, usually with limited increase in income, because peripheral clients are by nature scarce. If there is need to expand the transportation infrastructure, it is wise to go gradually, maybe first investing in a motorbike rather than a truck or lorry.

Quality Issues

In the pilot project, great emphasis has been placed on quality control, mainly in order to reduce the risk that substandard technical design would cause the project to fail. To some extent, this resulted in a very high standard on all levels, which probably to some extent caused the systems to be more costly than would have been the case with slightly simpler solutions. The energy regulator in Zambia, the Energy Regulation Board (ERB), has inspected the quality of installations. Staff of the ERB participated in some of the training activities in order to gain knowledge on solar PV, which previously they did not have. Subsequently, all installations have been inspected by the ERB. In general, the installations were of good quality from the beginning. Complaints in some cases were for poor placing of panels (shadowing) and sloppy workmanship in fixing panels and making holes in walls. These were subsequently rectified, re-inspected and approved. The role of ERB in this respect has certainly contributed to improved standards among the contractors, although not yet so much among the ESCOs, who took little part in the initial installations. In a growing PV market it is difficult to see that ERB could be able to inspect each individual installation, and quality control will have to be designed in a different way.

The Energy Regulation Board (ERB) is also the authority which accredits dealers in PV equipment in Zambia, and have developed a Code of Conduct, which the market actors are required to follow in order to get a licence. The ESCOs operate as private companies and are licensed to do business and installations of solar equipment by the ERB.

The formal purchase process

The competitive process applied in tendering for the supply of SHS to the project has had some drawbacks. The process applied is typical of other large-scale infrastructure projects and follows the national procurement laws of Zambia. Primarily, the extended time used for the procedure has had negative effects. As ESCOs were formed they quickly obtained quotations of interest from prospective clients. However, when delivery was delayed, the clients started to lose faith in the process, and some even withdrew their applications. The ESCOs also suffered from this delay, because technicians employed (and trained) for PV servicing opted to find other employment after a few months of waiting.

Another difficult aspect of the competitive process was that a direct relationship between suppliers and ESCOs was not formed. Furthermore, some of the conditions linked to the tender process made it impossible for some local suppliers to participate. This was mainly due to the very large guarantees required, and the extended credit periods necessary. A local company without international support is left to the local financial market for supply of credit instruments, a market that is severely deficient, and demanding very high premiums for its services. The result was that only companies with a substantial financial muscle, or in close connection to international companies were able to bid for the contracts offered. However, the final results were satisfactory from a quality point of view.

Capacity building issues

The project has supported the capacity building of the ESCOs through technical as well as business training. This training has been performed by the Physics Department at the University of Zambia, who with the assistance from consultants and some local PV dealers have developed a basic training course for installing and maintaining PV systems as well as an advanced course focusing more on battery maintenance and testing.

In the early stages of operation there was substantial ignorance from the side of the technicians in how to best ascertain continued operation of the SHSs. During this time several of the batteries took a heavy beating, and about 25 had to be replaced already before two years of operation had passed. This was largely because the systems were over-used, and although the users in time learnt that they could not press the batteries beyond certain limits, some of the batteries were not fully recharged ever, and had to be replaced.

A way forward

In order for solar PV to be able to contribute to improving the living conditions in rural areas of Zambia on a wider scale, much more than a pilot project is needed. From the experience of the pilot project it is clear that there is need for an infrastructure that can take on various tasks associated with PV development in rural areas.

The lack of a functional and dedicated financial market is one of the major constraints. The financial sector in Zambia is largely disinterested in serving the local market with viable financial instruments. Furthermore banks have limited and shrinking presence in the rural areas.

There is also a lack of a long-term stable proprietor in the sector. There are several tasks that a proprietor for solar development needs to take on in a scheme dedicated to fee-for-service delivery of solar electricity:

- Administrate capital provided by government and donors;
- Serve as a link between capital and end users (ESCOs);
- Be the intermediate owner of assets while ESCOs are paying their credits;
- Oversee the operation of ESCOs, and take action when some companies do not perform;
- Select new ESCOs coming into the market;
- Be aware of and coordinate ESCO activities with other development initiatives in the country.

In the traditional electricity sector these are all tasks of a national utility. Its role is to own, manage and develop the grid connection in the country. Although the utility could possibly play a role in solar PV development, the electricity utility has shown little interest in this sector so far.

While some of the tasks could theoretically be taken up by the private sector, the present situation with the banks precludes this solution. These are also not tasks for a government department, which does not have the mandate, skills and resources for the tasks at hand.

One proposed option to go forward is to create a new institution for the purpose, a Solar Facility. This institution could take on the responsibilities for the development of the solar PV sector, while interfacing with other government initiatives. It could be an institution with influence both from government, because government and donor funds will be handled, and from the private (non-government) sector, including rural stakeholders, existing solar energy service suppliers, etc.