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MONITORING AND EVALUATION OF SOLAR HOME SYSTEMS

Experiences with applications of solar PV for households in developing countries

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Acknowledgement/Preface

This project was conducted by the Netherlands Energy Research Foundation ECN together with the Department of Science, Technology and Society of Utrecht University, and obtained financial support from the Netherlands Agency for Energy and Environment Novem (project number: 146.610-401.1). Angele Reinders of Utrecht University contributed in an early stage of the project. After she changed from employer, Danielle Hirsch of Fusion21 was contracted to support the team. A crucial role was played by four senior PV experts; Hugo Arriaza, Mark Hankins, B.D. Sharma, and Herbert Wade. They assisted the team in obtaining information in different continents. Furthermore, Mark Hankins analysed for this project, maintenance information of more than 100 solar home systems in Kenya. B.D. Sharma formulated an analysis about developments in India, and Herb Wade summarised his extensive knowledge on experiences in the Pacific.

A database with project information played an important role. To make this information accessible we have modified the framework of the well-known Renewables for Sustainable Village Power database of NREL to make it suitable for this project. We thank Larry Flowers, Ian Baring-Gould and July Cardinal for allowing the use of the RSVP database.

Being a literature study, the project depended very much on the written materials that were provided to us by many people from all over the world. Some also provided additional background explanations. The list of people who contributed is too long to mention all names. We are very grateful for all the support provided.

Basically all the material presented here comes from literature sources with some additional information provided by authors or other experts. Quotation marks are used when a text is cited without any changes. Whenever smaller or larger modifications in the wording were made, no quotation marks were used. But in both cases the reference to the source is mentioned in the text.

Abstract

Solar energy is a promising solution to meet demand for electricity services of rural households in remote locations in developing countries. After some early successes, more and more doubts have arisen about the effectiveness and suitability of small PV systems for rural development. Many organisational, financial and technical problems appear difficult to tackle. A literature survey has been conducted to make an inventory of experiences with solar photovoltaic applications for households in developing countries.

The major conclusion from the extensive literature research performed during this study is that there is not enough information available about the performance of solar home systems and projects. This slows down further development and successful dissemination.

CONTENTS

EXECUTIVE SUMMARY

Solar energy is a promising solution to meet demand for electricity services of rural households in remote locations in developing countries. After some early successes, more and more doubts have arisen about the effectiveness and suitability of small PV systems for rural development. Many organisational, financial and technical problems appear difficult to tackle. A literature survey has been conducted to make an inventory of experiences with solar photovoltaic applications for households in developing countries. Furthermore, gaps in existing knowledge have been identified, which could be overcome by field monitoring programmes.

Introduction
This literature study aims at increasing understanding of the use of PV-systems in households in developing countries. Current knowledge is scattered over different sources, sometimes difficult to access and probably incomplete. An overview is provided of relevant experiences with household applications of solar PV.

Methodology
Only literature was reviewed that was more recent than 1992, and contains information about first hand experiences. Projects with sufficient information were entered in a database. We have adapted a version of the Renewables for Sustainable Village Power (RSVP) database of NREL [RSVP, 2000]. A finer subdivision in topics was made, especially in the area of “lessons learned”. No statistical analysis on the data was made except for a number of summary tables. The literature review focussed on four areas: experiences with institutional models, financing, technical aspects and user’s experiences.

Some statistical findings
An estimated 1.3 million solar home systems have been distributed in developing countries with a total capacity of around 40 MWp. About 79% of these systems is user-owned, another 13% owned by utilities in fee-for-service projects, and the remainder by cooperatives and private sector companies. About half of the projects have a size between 100 and 1,000 distributed systems. In more than half of the projects, a credit scheme increases affordability.

Models for dissemination of solar home systems

Introduction of solar home systems has started in a number of projects in the 1980s, funded by governments and bilateral donors. Projects continue to be dominant in most countries, while in a few others a commercial market has developed, completely driven by commercial interests. Projects were legitimated because the new technology required demonstration how to overcome key barriers to prepare the way for large-scale commercial implementation. Furthermore, some governments have an interest in implementing rural electrification programmes.

A more refined characterisation of the markets can be made based on the different arrangements for financing and ownership. The World Bank has defined four different institutional models for implementing SHSs [Cabraal, 1996]: cash sales, consumer financing through dealers and commercial banks, leasing arrangements, and fee-for-service. Each institutional model has specific characteristics with respect to ownership, financing mechanisms, flows of products, services and money. Here, we use a somewhat different division. Lease contracts with service arrangement are similar to fee-for-service. If leasing is merely a financial contract, there is little distinction with consumer credit. Instead of leasing we have added another model: donation by the government or a development organisation. These four institutional models cover both commercial markets and government projects.

Experiences with donations
Some of the early projects used the ‘donation’ delivery mode, implying that the donor provides the hardware for free or almost for free. Social objectives provide the motivation for donations of solar home systems. Users are generally less in involved and do not feel as much responsibility for the systems as compared to the case when they contribute a considerable part of the costs. Most of the donations are limited to the hardware only, often resulting in neglecting maintenance and service requirements. In a government programme in Tunisia, where the hardware is 100% subsidised, and only operational fee of $5.20 per was asked, people refused to pay for maintenance, because of the ‘free gift’ of the systems. This was not caused by an inability to pay, since some time later, people could afford US$ 208 for a grid connection.

Advantages of donation are low (often zero) initial costs for the user, the potential for cost reduction through economies of scale (purchase costs, transaction costs, installation costs), and rapid dissemination. However, past experiences with projects in which systems were donated has made this type of dissemination mechanism less popular (for example [Liebenthal, 1994], Annex 5). Usually, these projects failed because of lack of user commitment, and because it was not realised that the systems need maintenance for sustainable operation. In more recent projects, this approach is still used, taking into account the lessons that have been learned. In fact, one of the world’s largest SHS programs, the Mexican government program, donates systems.

There is ample experience with donations in large projects. In this type of project, the user is the key to sustained operation of the system. Donations can work provided the project contains provisions to create user commitment. The user must understand that he must maintain the system himself (or pay for it!) and save for replacements. This type of project puts high demands to the leading organisation, which has to decide whether a target group has the proper social and cultural conditions for this type of approach, and how user commitment must be created.

Experiences with cash sales
Main advantage of cash sales is the easy way of financing, the low transaction costs, and the high flexibility in consumer choice. Large (50 Wp) solar home systems can only be paid on cash by higher income households. Smaller (10-20 Wp) systems are affordable to larger groups of the rural population; for these systems, cash sales is the preferred mode of distribution. A problem with cash sales can be after-sales service, especially when the dealer of the system lives in the city and the buyer in the countryside. Kenya, Zimbabwe and China are the countries where almost all systems installed were obtained on a cash basis. Survey results from Kenya show that the status of systems is comparable or even slightly better than average with 10 to 21 % of systems in-operational. Cash sales in Kiribati before 1989 showed much higher failure rates with less than 10% of the PV were more than marginally operational.

Cash sales are an important market segment for SHS. Main organisational lesson learned is that systems paid on cash are liable to failure because there is tendency to go for a cheap, under-designed systems with low quality replacement components. There is a need for standards for components and system designs. Furthermore, reliable after-sales service is required to quickly remedy failures in system operation.

Experiences with consumer credit
Negative experiences with donations on the one hand and the need for finance on the other has resulted in the search for other more structural delivery modes. The provision of credit has for some time been considered the answer for widespread dissemination. With consumer financing, (part of) the funding for the solar home systems originates from sources outside the government budget such as banks or private companies. An advantage for the user is that the investment costs are spread out over a number of years. This improves affordability for larger parts of the population.

Most credit facilities are somehow linked to external parties who provide either the seed finance for establishing a revolving fund or financial guarantees of generally up to 100%. Without such support, local banks and other financing institutions are often reluctant to provide loans for non-productive investments to the rural population, which they generally perceive as a 'non-bankable' group. This perception is based on difficult and costly credit appraisal procedures, relatively high administrative costs - due to small loans, and frequent repayments - and lack of collateral.

A successful company was Sudimara in Indonesia, which sold about 7,000 systems in 2.5 years on 4-year credit terms [Miller, 2000]. Service was provided through about 50 solar service centres. Personnel received a bonus when fee collection was complete. However, continued growth was hampered by cash flow constraints and the business was stalled after the devaluation of the Indonesian Rupiah by a factor of three due to the financial crisis that started in 1997. This illustrates the vulnerability of credit schemes to unpredictable (external) financial shocks.

In Guatemala a credit scheme via an established micro-lender was unsuccessful with unsatisfied customers complaining about low quality products and lack of technical assistance to users [Arriaza, 2000]. No post-installation services were considered.

The overall impression of these credit schemes is that they can work reasonably well, in case good quality systems have been installed. The repayment discipline is strongly related to the technical performance of the system. If the system doesn't work, people stop their loan repayments.

Experiences with fee-for-service

Main advantages of the fee-for-service system are the spreading of costs to the user over a long period (more than 10 years), the usually easy access of the Energy Service Company (ESCO) to capital and the potential for cost reduction through economies of scale (purchase costs, transaction costs, operation and maintenance costs). Utilities are used to operate on a fee-for-service basis. However, up to now they have not been very eager to get involved in solar photovoltaics because of the high costs of rural electrification and the unfamiliarity with this new technology which is different from grid-electrification.

According to a study by ECN [ECN, 2000], despite benefits of a rental scheme, 93% of the surveyed households in Namibia indicated a preference for a credit facility. The underlying reason being that people like to own the asset they are paying for. Similar findings were found in a rural household survey in Swaziland were 95% preferred a credit scheme to a rental scheme. Those who preferred a rental scheme were expected to get a grid connection in the short run and regarded the rental scheme as an ideal interim solution.

In Kiribati, Pacific Islands, the private company SEC started in 1984 as a system supplier but decided to operate as an ESCO in 1989 (Annex 5). Since that time, SEC has operated as a rural utility. It sets up districts, with each district of sufficient size (50-125 systems) to be serviced by a SEC field technician. The user pays an installation fee of A$50 and a monthly fee of A$10-50 (depending on system size) to fully cover actual cost of operation, including battery replacement, and maintenance of the system. Every month, the field technician collects the fee and checks the equipment. Twice a year, a senior technician visits each district and audits the technician's performance. Evaluation teams from the EU (in 1998) and from Japan (in 2000) reported that SEC has been successful in both maintaining the systems and collecting the fees.

In the **Dominican Republic**, Soluz-Dominicana has been developing a fee-for-service model since 1996 [Cabraal, 1996]. In an extensive test phase with 200 customers, the model was refined. It is stated that the model is now cash flow positive with 1000 or more units (Philips

1999?). The same source mentions the following strongholds of this model. SOLUZ has set-up an excellent maintenance and after-sales service on the PV systems. Collection costs are low because users must put the monthly fee in lock-boxes that are located in prominent buildings. Local, independent collection agents are rewarded when collection levels are high; they report credit problems to SOLUZ before they are serious. SOLUZ has a credible repossession program, in which non-payment leads to quick and visible removal of the system. It is mentioned that the SOLUZ model is being replicated by SOLUZ affiliates in other countries. However, it is also mentioned that the financing of the trial efforts to prove the model was made possible by the personal efforts the director of SOLUZ: entrepreneurs without the proper connections will find it hard to use this model.

In 1996, the Federal Government of **Argentina** started a rural electrification program based on regulated concessions (see Annex 6) which have been granted in two provinces. In Jujuy, the private utility EJDESSA has installed about 700 SHS in a fee-for-service system. EJDESSA takes care of the supply, installation, and servicing of the SHSs. The Provincial Government of Jujuy contributes an additional subsidy. As a result, the consumer pays a monthly fee of only 4 US$. This is far below the estimated payment capacity of the users of 10-15US$ a month. In Salta, the ESCO that obtained the concession signed the contracts but installed no systems up to now because it underestimated the costs for installation and servicing.

We conclude that recent fee-for-service systems show opportunities to combine subsidies and market operation. However, the experience with the fee-for-service system is still limited. The projects in Kiribati and the Dominican Republic have demonstrated the viability of the service and maintenance schemes that were designed in these projects. However, the main challenge for this model is to organise operation and maintenance of the systems and fee-collection in a financially sustainable way, such that user contribution covers the costs for the ESCO. This has not yet been demonstrated.

To summarise the experiences with different delivery modes we conclude that for each delivery mode there are successful and none-successful case studies. There is not one best model: the choice for a model and the precise way it is set up depends on the institutional, legal, socio-economic and cultural conditions in the country.

The cost of solar home systems

Over the period 1989 to 1999 reported retail prices for complete solar homes systems were in the range of US$ 10 to 22 per Wp. Price information is often difficult to compare, some include cost of installation others only hardware. The generally prevailing perception is that the price of SHS is decreasing. However, for the data collected in the database, it is not possible to confirm the expected reduction in the price of PV hardware.

In most projects, the cost of batteries, and thus the need for financing battery expenditures, is not considered. The consequences are reflected in for example the projects in Mexico and Guatemala (Zacapa) where the scope for battery replacement is lacking and hence many systems do not or hardly perform. A positive example is the NRECA-approach (Guatemala), where communities have created a solar fund that will be used to replace the balance of system. The small monthly amounts that are contributed by the solar committee members are calculated in such a way that replacement can be made on time. For such a fund to function well, the administrators need to be highly trusted and frequently controlled by the committee members.

Evaluation of technical findings

A sufficiently high quality of solar photovoltaic system components is essential for a successful introduction of solar electricity for household applications. Frequent failures, even of small and cheap components as fluorescent tubes will cause user-dissatisfaction that will quickly lead to reduced incentives to continue repaying the fees if the system was not sold for cash. Well-designed systems with sufficient product quality are essential to make credit schemes or fee-for-service systems financially viable.

We have obtained information about systems with PV module capacities between 10 and 110 Wp. There is a clear peak in the number of projects in the range of 45 to 54 Wp. This appears to be determined by choices of project planners. Where users have sufficient choice, such as in Kenya, a large range of system sizes is encountered.

Performance of solar home systems
Only from a few projects and countries, information could be obtained about percentages of solar home systems that were found to be working or not working. These outcomes are summarised in table 1. Please note that the figures have to be interpreted carefully, since different methodologies have been used to assess the quality of the system. Also the lifetime of the systems in the field differ widely. For example, in the case of the Rama Krishna Mission in India, the systems were installed less than a year ago. Their excellent performance is therefore not a surprise.

Table 1: Overview of status of solar home systems (numbers are percentages of investigated systems)

<table>
<tr><th>Country</th><th>Good</th><th>Partly inoperational</th><th>Inoperational</th><th>Source</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Kenya</td><td>60</td><td>30</td><td>10</td><td>[Acker, 1996]</td></tr>
<tr><td>Kenya</td><td>77</td><td>2</td><td>21</td><td>[Hankins, 2000]</td></tr>
<tr><td>Tunisia</td><td>38</td><td>37</td><td>25</td><td>[AME, 1999]</td></tr>
<tr><td>India, RKM</td><td colspan="2">98</td><td>2</td><td>[TERI, 2000]</td></tr>
<tr><td>India, Urjagram’93</td><td colspan="2">51</td><td>49</td><td>[Annex 4]</td></tr>
<tr><td>India, Leh</td><td>71</td><td>27</td><td>2</td><td>[Annex 4]</td></tr>
<tr><td>India, Kargil</td><td colspan="2">96</td><td>4</td><td>[Annex 4]</td></tr>
<tr><td>Guatamale, Zacapa</td><td colspan="2">55</td><td>45</td><td>[Alvarez, 1999]</td></tr>
<tr><td>Mexico</td><td>76</td><td>21</td><td>3</td><td>[Huacuz et al, 2000]</td></tr>
<tr><td>Kiribati</td><td colspan="2"><10</td><td>>90</td><td>[Annex 5]</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>55</td><td>20</td><td>25</td><td></td></tr>
</table>

From the table it can be concluded, that in the dissemination activities for which information could be obtained, about a quarter of the systems is not working anymore, and an additional one-fifth of the systems is only partly operational. Batteries and fluorescent lights are the two components that cause most technical problems.

Battery quality
It is not always realised that batteries are usually the most expensive part of a solar home system over the lifetime of the system. Lifetimes of batteries vary considerably from project to project, from less than one year to more than four years. Usually, ordinary car batteries are applied which typically live between one and three years only in a solar home system.

Sizing of the battery, sizing of the PV module and battery maintenance are relevant for the lifetime. In Indonesia, locally produced batteries had substantially lower capacities than specified by the manufacturer [Fitriani et al. 1998]. Base on a sample of 555 batteries in Mexico, a rule of thumb was formulated that the battery capacity should be at least seven-and-a-half times the daily load in Ah [Huacuz et al, 1995].

Lights
Lighting is the most common application of solar home systems. In India, the common name domestic lighting system is also used when a television set is powered. Lighting with solar PV provides cash savings on fuels such as kerosene. In those cases where solar home systems are used for (indirect) productive applications, it usually involves lighting. Lights are often provided as an integral part of a solar home system.

The quality of different lights can vary considerably between more or less comparable lamp types. One lamp can have a ten times higher failure rate than a more or less similar lamp type. A problem in maintaining quality of lighting is the relatively small market for 12 Volt lamps. If a lamp breaks down, the user will always treat the whole system to be damaged. Therefore, lighting fixtures used in solar home systems should be as reliable as the rest of the system.

It was found that the number of lights required per system differ widely in different projects. It is clear that household demands are not equal. Programmes should allow for these large differences between demands of users.

There are still many remaining technical problems with PV systems for households. Quality aspects still do not receive sufficient attention. Improved charge regulator designs can contribute in protecting the batteries. Design changes need to be based on field experiences and feed back from users in different countries.

Evaluation of user's experiences

Socio-economic background of solar PV users
Although most government programmes are focussing on poor households in remote villages, there are still a lot of users in urban and peri-urban areas. Incomes of solar home system users is usually higher than average. Still the cost of a system amounts to a substantial share of family income, varying from one to six months salary. In Nepal, non-farm income was found to be higher than farm-income, which is related to the requirement of regular income to qualify for loans.

In Southern Africa the use of car batteries in unelectrified areas is common. For example in Swaziland 31% of the SHS users already had a battery and television set [Lasschuit, 1999]. Many obtain their systems via relatives with jobs in towns or abroad.

Energy demand
Most solar home systems are used for lighting. Electric lighting provides a step forward in quality and convenience and is less dangerous than kerosene lamps. Most solar home systems in the 35-55 Wp range are delivered with two or three lights. However, actually required number of lights may be higher. Small orientation lights are often installed later by the users themselves. Outdoor lighting is sometimes required.

Although lighting is the most common application, access to television provides a strong incentive for obtaining a solar home system. Black and white television sets are rapidly replaced by 12 Volt colour television sets. For radios, the added value of solar PV is often small due to voltages that to do not match. Surveys show continued use of small disposable batteries for radios and cassette players.

Energy service provided
User requirements vary widely, but a common finding is that users with larger systems are generally more satisfied with their systems. Appliances can be used for longer periods of time, and the systems are more reliable due less frequent deep-discharge of the battery [APTECH, 1995]. In most programmes the choice in PV-module capacity is small. In commercial markets, the evidence shows that there is a demand for a range of sizes to meet demand of different users.

It has been found that users do accept systems of lower quality and performance in an open market where the relation between price and quality is clear. In Senegal [Sarr, 1998], both user groups of systems without controllers and with higher quality but higher price were satisfied with their PV systems.

Maintenance and service are often underestimated in costs and efforts required. One of the frequently recurring complaints of PV users is the absence of a (functioning) maintenance and service scheme, or the cost of such a service.

User awareness and understanding of the system
Knowledge of the existence of solar electricity is sometimes high. About half of the un-electrified population in Namibia and Lesotho know what PV is. In Lesotho, 74% learned about solar homes systems by seeing a system in the neighbourhood or at friends, and 15% via radio. This illustrates the importance of the demonstration effect of well functioning systems.

User satisfaction depends on the understanding and expectations of the system. If people are accurately informed on the possibilities and limitation of a SHS, they know what to expect and can make an 'informed judgement whether to buy a SHS or not. Such people are generally more satisfied with their system than those who were promised 'heaven on earth'.

Ability and willingness to pay
In projects with cash sales and credit facilities it was found that the credit facility increases the ability to pay. A down payment acts as a rough selection mechanism. The willingness to pay strongly depends on user satisfaction. Credit instalments can be seen as a guarantee mechanism, as commonly users stop paying if the system does not function.

Conclusions

The main conclusion is that there is not enough information available about the performance of solar home systems and project. This hampers further development. In more detail the following conclusions were obtained:

1. Hundreds of solar home systems projects have been conducted in the past few years. For a considerable number of these, descriptions of the organisational set-up exist. However, only very few studies describe in some level of detail how solar home systems are actually used by households. Some early successes might have given the impression that everything is running well and there is no need to spend time and money in this stage on further research. But relatively high failure rates, even in recent projects, prove that there is still scope for improvements. More information is required to organise better dissemination activities, to decrease the default rate in credit schemes, and to improve the quality of hardware and installation of systems.
2. Establishing a viable distribution and servicing infrastructure appears to be one of the weakest parts in the dissemination chain for solar home systems at the moment. There are very few entrepreneurs that take the risk to establish a solar PV distribution and servicing company.
3. In countries with a commercial market for solar PV systems for households, extreme care is required in using hardware subsidies to support dissemination of PV systems. Subsidies can distort markets by providing unfair competition, especially to small start-up companies in production and distribution.
4. Projects supporting only a single type of solar home system should be avoided as far as possible. The largest density of PV-systems in an area can be attained if people have a choice in systems. It is especially important to include also smaller module capacities in the range of 10-30 Wp.
5. Institutional models for the dissemination of solar home systems are often exclusive. In a limited geographical area, the private sector market usually does not flourish if similar

systems are distributed in government programmes with heavy subsidies. Often existing programmes have a historical basis and are suited to local conditions.
6. The fee-for-service system is a promising mechanism from a sustainability point of view. However, there is only limited information available about the pros and cons of this scheme.
7. Credit schemes are useful to improve affordability and thereby increase access of middle income households. An alternative to reach this consumer group can be the use of smaller, modular systems.
8. The limited information available about experiences with PV for households is often difficult to access and is scattered over different sources. This information is extremely valuable to improve design of new projects. To facilitate exchange of information, a database with project information is very useful.
9. Batteries and fluorescent lights are the two components with the most frequent failures in solar home systems. Protection of the battery can be enhanced by improved charge regulators, which are currently of simple design. Also the quality of the production process is often low.
10. Markets are not sufficiently transparent at the moment. Good products are available, but users need information to make their choices on the basis of price-quality ratio.
11. Countries with government support for solar home systems, often apply sets of requirements for systems and components to become eligible for inclusion in programmes. However, we could not obtain evidence that systems in countries with these requirements perform better than systems in countries without government requirements.

Recommendations[1]

1. To increase insights into the use of solar PV in households, monitoring and evaluation activities are required, using as main instruments, data loggers and household surveys. Monitoring needs to be continued after dissemination projects end.
2. Strengthening the distribution and servicing infrastructure is necessary, for example by supporting human resource development in small and medium scale enterprises.
3. To limit possible negative effects on local production of BOS components, hardware subsidies can best be directed to the module only and have a ceiling determined by price differences on the local market.
4. The viability of a distribution and servicing infrastructure can be enhanced by including solar lanterns and solar battery charge stations in solar home system projects. Wishes of the user concerning the number and location of lights and suitability for other appliances must be taken into account.
5. External (financial) support should focus on strengthening existing programmes rather than to support completely new activities that compete with existing programmes.
6. Careful monitoring and evaluation of fee-for-service systems in different countries can contribute to make it a success.
7. Monitoring and evaluation of solar home systems that are sold piecemeal instead of in kits will contribute to more information about the characteristics of this market, allowing for design of better products and more efficient marketing. Replacements and maintenance must be affordable and available for end-users.
8. We recommend maintaining and extending the database constructed in the framework of this project with new information about projects and markets.
9. To enhance product quality of solar home systems, improved designs of fluorescent light inverters and charge regulators need to be developed. Companies need assistance to improve their production processes through training and support in establishing joint ventures.

[1] Recommendations 1, 2, 8 and 9 were presented and discussed in a workshop in Utrecht on 17 May 2000. There was general support for 1, 2 and 8. Recommendation 9 was rejected by the participants of the workshop. Recommendation 10 was suggested by one of the participants, and this received support of a majority.

10. The role of end-users needs to be strengthened by empowering end-users for example by having independent consumer organisations compare the different products on the market.
11. Field monitoring, complemented with laboratory tests are required to achieve a stronger feedback from experiences with actual quality in the field towards formulation of standards and requirements by national governments as well as IEC and PV-GAP.

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1. INTRODUCTION

Solar energy promises to serve electricity demand of scattered households in developing countries. Some early successes made solar home systems a popular alternative for grid extension. In a number of countries the World Bank and bilateral donors, assisted governments with ambitious dissemination programmes. Recently, more and more doubts arise. Few projects were sustained after the external support ended. Many organisational, financial and technical problems still come up each time. Despite the high potential, the introduction of solar PV in developing countries turned out to be a difficult process, which developed slower than expected. But, does that mean that there is no role for solar home systems in rural electrification? Certainly not, since there are also dissemination activities which show sustained development. But the limitations of solar home systems should be faced and overly optimistic scenarios prevented. Exchange of lessons learned will contribute to improve success rates of projects.

1.1 Objectives

The study aims at increasing understanding of the use of PV-systems in households in developing countries. Current knowledge is scattered over different sources, sometimes difficult to access and probably incomplete. This literature survey intends to provide an overview of relevant experiences with household applications of solar PV. Furthermore, it intends to map gaps in existing knowledge, which could be over come by field monitoring programs.

In the context of this study, field-monitoring programs are defined here as all field-based activities to gather information on the operation of solar PV applications for households. These can be technical (such as defects of components, and repairs required), or related to financing (ease in obtaining a loan, difficulties with repayment schemes), related to communication (promotion of systems, raising expectations, and problems with understanding maintenance requirements, or the text manual) and so on. But, the focus will always be on the household experiences.

1.2 Scope of work

Household applications of solar PV in developing countries are limited here to the following three systems:

(a) Solar home systems are defined here as small PV systems consisting of one or more solar PV modules with a total peak power of 200 Wp or less and a battery. These are used for powering household appliances such as lights, radio, television and fans. Both AC and DC systems are included.
(b) Solar lanterns consist of a PV-module and a portable light with a battery.
(c) PV-battery charging stations have an array of PV modules, which are used to charge batteries for individual households. These can be used for powering home systems and portable lanterns.

Excluded are small PV mini-grids, PV-pumps, lighting and refrigeration for rural clinics, and all other non-household applications.

Existing, written information was the prime source of material for this literature survey. However, in case a given publication needs clarification, additional information was requested from the authors.

The study was limited to household applications of PV in developing countries. An advantage of this choice is the relatively well-defined usage patterns and the limited size of the systems.

1.3 Solar energy for households

About two decades have passed since the first solar home systems were installed in developing countries. Hundreds of companies and other organisations followed and at the moment they have been introduced in practically all countries of the world. A lot of experiences have been obtained in numerous projects, although this information is not always easily accessible.

A number of successful pilot projects received wide-spread attention. After these success stories, solar home systems gradually became adopted as a viable option to provide electricity services to rural people in developing countries. Besides projects, a commercial market developed in countries with suitable circumstances.

Currently, an estimated 1.3 million solar home systems have been installed. Yearly about 250,000 more are added. About one-third of these are distributed with subsidies in donor funded and government programmes and two-thirds via commercial dealer sales. The number of solar lanterns is more difficult to estimate because The only reliable figure we could obtain was the number of 280,00 lanterns in India. This implies that of the 50 million households gaining access to electricity each year, about 1% uses solar PV.

Projects such as Sukatani in Indonesia established the viability of the solar home system concept. However, not everything is going well with solar PV for households. Early projects faced many technical problems, mainly with charge controllers and lights. Setting up sustainable PV-businesses turned out to be more difficult than expected. Only very few examples exist of commercially viable companies that go beyond selling equipment and also provide installation and after-sales services.

Solar home systems can be distributed in a number of different delivery modes. Most of them fall under one of the following four categories:

- Cash sales by commercial dealers (Kenya, Zimbabwe, China);
- Donations in the form of onor-funded demonstration and institutional development projects (India, Mexico), where users pay at most a small contribution to the total costs;
- Credit schemes (Grameen Shakti in Bangla Desh, Sudimara in Indonesia)
- Energy service companies with fee-for-service systems (Kiribati; South-Africa, Argentina);

Usually one of these delivery modes is dominant in a country or region. It appears that in case of limited rural distribution grids and absence of rural electrification programmes, commercial dealers can meet the un-met demand for electricity services. This is the case in most African countries. With extensive rural electrification programmes, such as in many Asian countries, and in three major Latin American countries, most middle-income households are already connected to the grid. The remaining households are relatively poor and can only afford solar PV when subsidies and credit facilities are provided. Financial support is justified by the strong social and political objectives associated with rural electrification.

Relatively few projects and programmes have been monitored, and not all results are accessible. Some interesting field findings show up. Field tests in Kenya showed that the current generation of high quality amorphous silicon modules perform as well as crystalline modules. Experiences in Kenya and Gansu Province in China showed that when people are presented with a choice, the smaller 10-20 Wp units are preferred over standard 40-50 Wp modules. Furthermore, failure rates differ widely from country to country and between projects within a country. It is estimated that on average about one quarter of the solar home systems that have been installed do not work properly.

This does not imply that these are all ‘written-off’! Malfunctioning lights and failed batteries that will be replaced as soon as the required cash is available, only mean temporary unavailability of service. But the message is clear: there is still a lot of scope to improve the quality of systems, installation and after-sales services. Continued quality enhancement is crucial to accelerate the introduction of solar home systems and to really make solar PV a universally accepted option for rural electrification. This study is intended to contribute to this process by summarising world-wide experiences with solar PV applications for households.

1.4 Number of installed solar home systems

An estimate was made of the total number of installed solar home systems by adding the figures for a number of countries and make the assumption that in the rest of the developing countries the share of the total population with solar home systems is 0.1%. According to this first estimate, about 1 million solar home systems have been installed up to now as can be seen in Table 1.1. In the last column a calculated share of the total population of the country is given, based on an assumed average household size of 5 persons.

Table 1.1: Distribution of installed solar home systems in developing countries in 2000

Country	Number of SHS installed in 2000	Total population in millions in 1998*)	Share total population with SHS [%]
Kenya	150,000	29.3	2.56
India	118,000	980	0.06
China	(est.) 100,000	1239	0.04
Mexico	90,000	96	0.47
Indonesia	80,000	204	0.20
Zimbabwe	80,000	11.7	3.42
Morocco	50,000	27.8	0.90
Other developing countries (estimate)	*390,000*	*1948*	*0.10*
Total (estimate)	1,058,000	4536	0.12

*) Source: World Development Indicators 2000, World Bank.

Some of the figures in this table reflect only the number of systems distributed through government programmes. Systems sold via the commercial market, especially the smaller, amorphous silicon modules are underrepresented in this table. Based on estimated sales figures of three amorphous silicon module suppliers, it is estimated that an estimated 10 MWp of amorphous silicon modules have been applied in solar home systems. This is equivalent to about 1 million modules. Assuming that on average two modules are used per solar home system, and assuming that 50% have been included already in this table, an estimated 250,000 systems have not been included in the table. In total, the project team estimates that about 1.3 million solar home systems have been installed world-wide.

1.5 Issues in household use of PV in developing countries

Solar home systems are a financially and economically viable option for rural electrification in case people live scattered and when electricity demand of each household is very low. In many rural areas in developing countries this is a common situation. There is a steady increase in the number of solar home systems but this is far from the rapid growth that most people expected. A major barrier is the high up-front investment costs of the systems caused by the high price of the solar PV modules. However, even with substantial subsidies (such as the government programmes in India and Mexico) or when access to loans is available (IREDA loans in India, World Bank loans in Sri Lanka Indonesia and Zimbabwe, Government loans in Botswana and Namibia, bilateral projects such as Bolivian High Plateau, Genesis in Guatemala) the growth is still limited. This is an indication that there are a number of other issues, which are as important as the first cost barrier. In this paragraph we will highlight some of the main questions and issues in the present PV-SHS discussions, to provide a mindset for the following analysis.

1.5.1 High costs of solar photovoltaics

Solar electricity is very expensive per kilowatt-hour. But when only small quantities are required it is often the least cost solution, especially in remote areas. Initial costs are high compared to some alternatives such as a small generator. But the running costs are often lower than those for the alternatives. As a result there is an incentive to reduce the first cost barrier through subsidies and credit schemes.

Expectation of lower costs for PV-modules in the future is sometimes mentioned as a justification for temporary subsidies. This is not a valid argument since the cost of solar home systems is not expected to decrease rapidly in the near future. On a life-cycle basis the battery is the most expensive component and not the PV-module. Cost decreases in batteries are not expected in the short and medium term. Off-factory prices of solar home systems will not become substantially lower soon. We have to live with the fact that solar electricity is not an option for the poorest of the poor. Nevertheless, , substantial lower costs for households can be achieved by supplying smaller systems. Furthermore, distribution and servicing costs can be reduced when higher densities of users are achieved. In some countries, high import barriers result in unnecessarily high cost for users of solar home systems compared to generator users.

We will explore whether and how differences in costs from country to country and between projects, affects dissemination of solar PV for household applications. There are some indications of commercial successes with cheap solar home systems, but also successful implementation efforts with high cost systems.

1.5.2 Is there a need for subsidies?

Subsidies are provided to increase access of middle income households to expensive solar home systems. From a supply-side perspective, they can contribute to create a sufficiently large market demand for viable PV businesses, both in production and in distribution. Dangers associated with subsidies are the limits to government budget allocations, the incentives for corruption and inefficiencies, and the disruption of commercial developments. However, there seem to be numerous reasons for providing subsidies under certain circumstances, for example to develop and protect a new industry or to meet broader social development objectives.

Levels of subsidy in projects in different countries have been investigated in this project. Under what institutional settings can subsidies be useful, what is the relation between the evolution of commercial market mechanisms and subsidies, and what is the role of the private sector and the users in a subsidised initiative?

1.5.3 Role of governments

Government involvement in solar PV for households exists on many different levels. Rural electrification policy in some countries contains the objective to electrify all rural households. Support mechanisms are state funding for research and development, support to small and medium scale enterprises, fiscal incentives and a level playing field with conventional alternatives, provision of subsidies, facilitating training and funding rural electrification projects.

The present document analyses the very different roles of different Governments in countries and regions, and the strong and weak points in their respective dealings with the introduction or support of PV in their countries.

1.5.4 Utilities

One of the modes of large scale dissemination of solar home systems which becomes increasingly popular is the fee-for-service system, in which utilities own the systems and users pay regular fees. Most utilities have been reluctant to become involved because of inexperience with distributed systems and the perceived lack of commercial viability of SHS vis a vis other forms of electrification. However, in some countries the spread of solar home systems is dominated by utilities.

What determines the success of utility PV projects? Have they been able to develop commercially sustainable activities?

1.5.5 Role of Multilateral Development Banks and bilateral donors

It has been about a decade ago since preparations for large-scale renewable energy projects in the World Bank started with the FINESSE project. For a number of countries World Bank loans with a solar home system component exist and in a number of other countries they are still in preparation. However, no large-scale dissemination funded by the World Bank has started yet.

Bilateral donors have been somewhat more successful in funding large-scale dissemination. But there is often a supply-push to support the local industry of the donor country. Export subsidies reduce system costs, and create large markets. This can help in reaching quantitative targets, but sustainability after the project ends remains unclear

Given these apparent difficulties, the role of multilateral development banks and bilateral donors as active players in the PV sector becomes an issue for debate. Will there be a shift in focus from establishing projects to contributing to an enabling environment by supporting (entrepreneurial) training and providing assistance to integrate solar PV in national rural electrification planning and utility planning? Or will their role be decisive in those countries where market opportunities are less obvious and a commercial mechanism is not likely to evolve?

1.5.6 Arranging small-scale financing

Lack of availability of credit facilities at the consumer level is often cited as a major barrier. Many rural (development) banks are reluctant to provide credit for non-productive purposes. In some countries the suppliers of consumer durables provide credit to their rural customers. There are few examples where commercial solar home system dealers provide credit. On the other hand there are examples of large scale dissemination without supporting credit facilities.

As is the case with subsidies, credit might be less crucial than perceived earlier. What are the lessons learned in existing credit programmes? Can a recipe for success be distilled from existing experiences?

1.5.7 Scaling up projects

Smaller solar home systems (<30 Watt) are often obtained as separate components, first the battery, then a PV-module, which is sometimes followed by a charge regulator or an additional module. The larger solar home systems are often distributed via projects. Instead of the user, a professional installs the systems. Establishment of a distribution and servicing infrastructure requires specific human resources. Training is important, but requires time before its impact becomes visible. Planning large, stepwise increases of the sales and distribution targets have to take into account these limitations.

1.5.8 Household choice

The initial success of a number of demonstration projects with solar home systems around 1990 made the 35 Wp to 55 Wp module with a number of lights and a socket for radio or television the ‘standard’ size. Currently, most solar home systems in the world are within this range. Often, rural dwellers do not have much choice: government programmes or government subsidies are limited to one or only a limited number of system designs. And even in the private sector it is quite common that companies offer only a single design. The Kenyan PV market offers a wide range of system sizes. A large percentage of the systems are small (12 Wp size) and are often sold as separate components. The success in Kenya illustrates the importance of sufficient choice. Providing opportunities for choices is also very important for options to finance the systems or obtain subsidy, possibilities to choose between different suppliers, different designs and different quality and price levels. With respect to quality, people tend to be willing to reduce their demands on quality in exchange for the possibility to acquire a cheaper system.

The relation between successful implementation and providing sufficient choice is still largely unexplored. Questions arise such as the need for a well developed dealer network to increase user’s choices, the possibility of determining the ‘standard’ demand of people within a region – thus reducing the need for choice- and the role of information provision to the users vis a vis the need for choice.

1.5.9 Low quality of components

Experiences with technical problems with solar home system components differ widely. Some systems do not function from the start, while others work for 10 years without major problems. Sometimes good quality components fail more rapidly than foreseen, due to wrong use. In other cases, the quality level is low because of inadequate designs or lack of quality control during production.

The question as to the need for quality standards and the ways to control these are discussed in the analysis, as well as the need for a further search for better components, in order to improve the overall quality and sustainability of SHS.

1.6 Research methodology

Criteria for selection of literature
There may be thousands of publications on solar PV for household applications. Therefore selection criteria are required to guide the choice of literature. These criteria are:

- Emphasis is on recent publications, since experiences have developed rapidly in the past few years. Relevant experiences of the past are supposed to be also included in more recent material. Only with very good reasons, material was included with a publication date earlier than 1993.
- Material must contain information about first hand experiences;
- The intention was to obtain at least some information about each developing country.

The following sources of information have NOT been reviewed: feasibility studies, descriptions of programmes, and project proposals.

Sources of literature
Different printed sources have been utilised: books, reports, conference proceedings, project evaluations, student thesis, Ph.D. thesis, magazines and newspaper articles, web-sites, leaflets, supplier information and newsletters.

Means to obtain information

- Searching the open literature. Books, reports and publications were obtained via libraries, directly via authors, and via the internet.
- Visits were made to a number of research institutes and other organisations dealing with solar PV in different countries.
- Email contact with experts that were often approached initially through a standard letter, with the project summary in English, and a request for available information

- E-mail contacts or telephone interviews with the authors of reviewed publications.
- Personal visits to some of the authors of publications.

Resource persons
Four senior experts were subcontracted to assist the project team in data gathering in the four continents. Each of them also formulated a summary, which is attached to this report.

Database
A database with project information played an important role. To make this information accessible we have modified the framework of the well-known Renewables for Sustainable Village Power database (RSVP)_of NREL to make it suitable for this project [RSVP, 2000]. In the modified database, which we call the RSVP-ECN database, a finer subdivision in topics was made, especially in the area of "lessons learned" (see Annex 3 for the complete list of items in the RSVP-ECN database).

Existing and accessible information: the basis for this analysis
We have relied almost exclusively on written information, and only to a very limited extent to own observations during field trips. A number of authors of publications have provided some additional information. But almost everything that is described in this report can be directly traced to written materials.

There is an important disadvantage to this approach. A serious bias is caused by the fact that very few reports and articles describe activities of commercial dealers who distribute systems on cash sales. Another selection effect was caused by the fact that of most ongoing projects no written information exists yet.

1.7 Contents of the report

We conducted an analysis of the data from the viewpoint of four main themes: institutional aspects, financial aspects, technical findings and user experiences. These themes cover most of the aspects around dissemination of solar PV for household purposes in developing countries. In the main report each of these themes is covered by a separate chapter. Main conclusions and recommendations are formulated in chapter 6. In Annex 1, a summary of data base results is presented, in Annex 2 the projects in the data base and in Annex 3 the format of the information in the database. The contributions of the resource persons are presented as Annexes 4, 5, 9 and 10. Annexes 6, 7 and 8 are the country reports for Argentina, Brazil and Mexico.

1.8 References

[RSVP, 2000] NREL, 20000, Renewables for Sustainable Village Power. http://www.rsvp.nrel.gov/

2. INSTITUTIONAL ASPECTS OF PV PROJECTS AND PROGRAMMES

2.1 Introduction

Since it was recognised in the 1980s that solar home systems can be the least-cost option for rural electrification, solar home systems have been introduced in many countries. In some of them, for example Kenya and Zimbabwe, free markets for SHS have developed. In other countries, such as Mexico, India, and Indonesia, SHS are disseminated in projects, financed by the government or bilateral donors. There are examples where free markets and projects function in parallel, with one of them dominant, for example in Mexico where the federal government programme has installed about two-thirds of the total number of systems. However, it has to be investigated whether free markets and projects can co-exist in a sustainable way.

Projects are done for two different reasons. One reason is that solar home system technology is radically different from conventional grid-electrification: projects should demonstrate how to overcome key-barriers for successful dissemination and prepare the way for large-scale commercial implementation. A second reason for doing projects is that governments want to bring electricity, considered as a basic right of all citizens, to the target group.
The World Bank has defined four different institutional models for implementing SHSs which are named after the financing mode [Cabraal, 1996]: cash sales, consumer financing through dealers and commercial banks, leasing arrangements, and fee-for-service. Each institutional model has specific characteristics with respect to ownership, financing mechanisms, flows of products, services and money. In practice, the difference between consumer financing and leasing arrangement of solar home systems is not so large. Therefore, in this study we consider both consumer financing and leasing arrangements as two representations of one institutional model that we call “credit”. Here, we add as a fourth institutional model: donation by the government or bilateral bank. These four institutional models cover both commercial markets and government projects.
It is generally accepted that an institutional model for successful implementation is country specific (see for example [Cabraal, 1996] and [Cabraal, 2000]). What model is most suitable for a country depends on the institutional, legal, socio-economic and cultural conditions in the country. Furthermore, a project can only be successful if every part of the institutional model is functioning properly: if one part is weak, the entire project may fail. As a consequence, it may take several projects to find a successful approach for a country.

In this chapter we investigate the experiences that have been gained with each of these four institutional models. We want to show what are the crucial factors to make a model successful and why a particular model can be successful in one country but not in another. We will draw conclusions on the various organisational aspects of the models. It should be noted that criteria for success are usually not specified in a project. Therefore, we will here propose criteria for success.

It is not possible to discuss all projects that have been done world-wide. Rather, we focus on the few projects that are well-documented and are clear cases of success or failure, and generalise the lessons learned. As a consequence, the selected projects may not be a fair representation of projects done up to now, but they provide new insights and lessons for better project design.

We will first describe the institutional models and our criteria for a successful project (Section 2.2). Next, we will discuss the experiences with different types of projects (Section 2.3 to 2.6).

Finally, we will describe the lessons learned on these aspects for different perspectives/actors in the project (Section 2.7).

2.2 Institutional models and criteria for success

The four institutional models for the dissemination of SHS that we use in this study are shown in Table 2.1. Here we briefly mention the main characteristics of each institutional model. An elaborate discussion on the characteristics of each model can be found in [Cabraal, 1996].

Table 2.1: Institutional models for dissemination of SHSs

Institutional model	**Ownership**	**Financing**	**Maintenance**
Donation	customer	government, international donor	Customer
Cash sales	Customer	n.a.	Customer
Credit	Customer, intermediary (-> customer)	commercial bank, coop, dealer, international donor	customer service company
Fee-for-service	Energy Service Company (ESCO)	ESCO	ESCO

In case of **donation**, the end-user or sometimes a co-operative becomes the owner of the entire system. The system is financed by the government or by a foreign donor. The contribution of the owner is often smaller than 10%. Service, consisting of the maintenance of the system and replacement of components, is the responsibility of the owner.

Customers can buy a solar home system for **cash** from a local dealer. Servicing is the responsibility of the customer, and is usually provided by the private vendor on a fee-for-service basis.

In case of **credit**, the customer buys the solar home system under a credit arrangement. The World Bank distinguishes two ways of credit: consumer financing and hire-purchase [Cabraal, 1996]. *Consumer financing* is provided by the solar-home-system dealer or a commercial finance organisation. Sometimes, the solar panel is the loan collateral. Under a *hire-purchase* (or leasing) arrangement, an intermediary retains ownership of the SHS or some of its components until the cost is recovered. Systems are supposed to be removed when users default their payments. Donors or government may provide grants to buy the SHSs. Managing of the project is by an intermediary (for example an NGO), who purchases the systems, collects the monthly fees, and takes care of administration. Once the loan is paid off, ownership transfers to the customer. For solar home systems, in practice the difference between consumer financing and hire-purchase is usually not large In many credit arrangements it is stated that ownership is transferred to the user only when the loan has been paid fully back to the supplier or the bank: this equivalent to hire-purchase. In a credit scheme, service is through an annual service contract or on a fee-for-service basis.

An energy service company (ESCO) sells the energy service but retains ownership of the system indefinitely. The energy service company can be a private or public utility, a co-operative, NGO, or a private company. The consumer pays a fixed monthly fee for the service or pays for the amount of energy consumed (**fee-for-service**). Financing and servicing of the SHS is done by the ESCO.

It should be noted that in all models, the government can bring in permanent subsidies if it is of the opinion that rural consumers should not carry the full costs of electrification.

What defines the success or failure of a project is usually not specified in the project. Following van der Vleuten *et al.* [Vleuten, 2000], we propose the following criteria for a successful project.

For a non-commercial project:

- The installed systems must provide a sustainable energy service;
- The project must develop a new infrastructure for deployment of future systems.

For a commercial project:

- The installed systems must provide a sustainable energy service;
- The project must create a sustainable market.

Sustainability measures the long-term impact of a project. In the operation of PV systems, problems with batteries usually start to occur after a period of three years. It takes time to develop new infrastructure or to prove sustained sales of PV systems. Therefore, we propose that for solar home systems a period of 5 years after the start of the project is the minimum period for investigating the sustainability of a project.

2.3 Experiences with donations

Motivation for donations is social development. Advantages of donation are low (often zero) initial costs for the user, the potential for cost reduction through economies of scale (purchase costs, transaction costs, installation costs), and rapid dissemination. However, past experiences with projects in which systems were donated have discredited this type of dissemination mechanism (for example [Liebenthal, 1994], Annex 5). Usually, these projects failed because of lack of user commitment, because it was not realised that the systems need maintenance for sustainable operation. In more recent projects, this approach is still used, taking into account the lessons that have been learned. In fact, one of the world’s largest SHS programs, the Mexican government program, donates systems. Here we discuss the experiences with several recent projects (see Table 2.2).

Table 2.2: Examples of Solar Home System Projects implemented as donations

Country	**Donor**	**Donor Name**	**Period**
Mexico	Federal government	Federal Government of Mexico	1989-now
Tunisia	Federal Government	Government of Tunisia	1993-now
Guatemala	bilateral donors		1994-now
Guatemala	NGO	PLAN International	1995-now

It is estimated that under the federal government program of **Mexico** that started in 1989 50,000-100,000 solar home systems have been installed (see Annex 8). The user receives the system from the government and is responsible for the maintenance. The federal government pays the systems (for 90-100%), guarantees the quality of the SHS, and trains the users. In the project, two phases can be distinguished: the first phase under the former government (88-94), and the second phase under the current government (94-00). The main difference between the two phases is the shift in the role of different stakeholders. In the first phase:

- a municipality or community submits a demand for electricity to the Secretary of Social Development, who channels the petition to the
- Comisión Federal de Energía (CFE). The CFE has a widely spread network of regional and local representatives. The network of CFE buys systems, and distributes them following the demands made. The selection of communities depends among others on their need for subsidies and their political role in a region. CFE issues calls for tenders, and receives the

offers of various companies in the country for a large number (500–1000) of systems. The tenders demand an offer for the systems, the installation of systems and service.

- The federal Institute for Electricity Investigation (IIE) had developed a quality protocol that describes the minimum standards of the systems. The IIE has provided technical support to CFE since the first installation of SHS. They provide training, design protocols that have to ensure the quality of the systems and system installation and service, and monitor and evaluate the systems.

In the second phase the municipalities have become the main decision-maker in the development and installation of SHS. In the first period, the development of SHS was mainly led by the institutions (i.e. IIE and CFE); in the second phase, the responsibility for training was moved from CFE to municipalities and companies.

Evaluation of the government programme is going on but has not been published yet. It seems that not all systems are working properly. In most cases this is related to bad maintenance and the lack of spare components. In spite of these problems, the model has been successful in bringing large numbers of SHSs to customers, who cannot be reached by commercial SHSs or grid-electrification. Donation may work in a country where people are accustomed to free public goods and services and to taking due care of the gift. However, the financial sustainability of the program is not clear.

Under the National Programmes in **Tunisia**, the user received the SHSs from the government almost for free [AME, 1999]. In the first two years after installation, service had to be provided by the government organisation AME, l'Agence pour la Maitrise de l'Energie. There were many technical problems, which were handled by AME. After two years, AME had to stop the servicing, because of lack of money. It was expected that after two years local companies would deliver service on a commercial basis. It appeared that servicing was not economically viable because of the dispersed settlements of the users.

In phase I of the Zacapa project in **Guatemala,** SHS were donated by the NGO PLAN International. Users were responsible for repair and replacement. Training to the users was provided by the NGO Fundacion Solar, who mentioned the need to start savings for battery replacement directly from the outset of the project. Fundacion Solar evaluated the project after 5 years [Alvarez, 1999]. Of the 124 systems evaluated, 45% was not working. In spite of the training, the users were not able to correctly repair basic failures; one of the reasons was that training was not directed at the principal users (women). Generally, failure of ballasts and regulators caused fluorescent tubes to burn out. When replacement of the tubes did not prevent new failures, use of the system was stopped soon. In general, the higher the number of appliances, the better the systems were maintained. Furthermore, savings for the battery replacement were not made because of the absence of a custom of long-term savings in these rural communities. In phase II of the project villagers had to pay for at least 40% of their systems: it was observed that they were more likely to provide proper maintenance to their systems to avoid damaging their investment and begin saving early. It was concluded that user contribution to the investment provides an incentive for sustained operation of the systems.

We conclude that there is ample experience with donations in large projects. In this type of project, the user is the key to sustained operation of the system. Donations can work provided the project contains provisions to create user commitment. The user must understand that he must maintain the system himself (or pay for it!) and save for replacements. This type of project puts high demands to the leading organisation, which has to decide whether a target group has the proper social and cultural conditions for this type of approach, and has to create user commitment. The projects show that these attempts have rarely been successful. It is interesting that in this project type tendering of commercial suppliers can be used to bring in competition and increase efficiency.

2.4 Experiences with cash sales

Main advantage of cash sales is the easy way of financing, the low transaction costs, and the absence of financial risk for the supplier. A disadvantage of cash sales is that the larger systems (50 Wp) are limited to the higher income groups. For the less well-to-do only smaller (20 Wp) systems are affordable. A problem with cash sales can be after-sales service, especially when the SHS dealer is based in town and the user in rural areas. Table 2.3 shows a few examples of SHS activities implemented as cash sales.

Table 2.3: Examples of Solar Home System activities implemented as cash sales

Country	**Dealer**	**Dealer Name**	**Period**
Kiribati (Pacific)	Private company	SEC (Solar Energy Company of Kiribati)	1984-1989
Kenya	Private company	15 companies	1985-now
Mexico	Private company		1989-now
Morocco	Private company		

In **Kiribati,** Pacific Islands, national involvement with PV for general rural electrification started in 1984 with the formation of the Solar Energy Company of Kiribati (SEC) (see Annex 5). SEC sold PV systems and provided service on demand. The PV systems were sold for commercial prices but labour for technical support was offered at essentially no cost due to USAID grants. In 1989 SEC was almost bankrupt. A survey in 1992 showed that at that time less than 10% of 270 PV systems were more than marginally operational for the following reasons. The householders bought undersized systems and cheap replacement components to save money, they were unable to properly install the system in spite of the availability of instruction materials and unwilling to pay for professional installation at essentially no cost, householders did not recognise the value of preventive maintenance, and travel costs of a maintenance visit was higher than most users were willing to pay because of the low system density. In 1989, it was decided to operate SEC as an ESCO.

Several studies for **Kenya** show that not all systems are fully operational (see for example [Acker, 1996], Section 4.2 and Annex 10). These studies also mention that part of the faults were remedied under warranty.

In **Mexico**, there is a large group of high income rural inhabitants, who buy large SHSs cash on the private market. Performance data of these systems are not available, however, the continued sales may indicate the user satisfaction with the system.

We conclude that cash sales are an important institutional model for SHS. Main organisational lesson learned is that systems paid on cash are liable to failure because there is tendency to go for a cheap, low-quality system that is often under-designed and cheap replacement components that are often not fully compatible with the system. There is a need for standards for components and system designs. A wider range in systems may prevent badly designed systems. Furthermore, reliable after-sales service is required to quickly remedy failures in system operation.

2.5 Experiences with credit

In case of credit, at least part of the funding originates from a party that is not the user; this funding has to be paid back, usually with interest. Advantage of credit for the user is the spreading of costs over a certain period. As long as the systems are the property of the financing institution, this institution has the responsibility that the systems function properly. This will support the use of high quality systems and servicing. A problem can be to find an actor that is willing to operate as a financier. Commercial banks are not accustomed yet to solar home system and may perceive them as a risk. For international financiers, providing credit for solar home systems may be an opportunity to stimulate the introduction of solar energy. Here we will discuss the experiences with credit for solar home systems (see Table 2.4).

Table 2.4: Examples of Solar Home System Projects implemented with credit

Country	Financier	Financier's Name	Period
Philippines	church-based co-operative Saint Joseph's Credit Union (SJCU)	Development Bank of the Philippines (DBP)	1993-now
Indonesia	Solar company	Pt Sudimara	1994-1999
Bangladesh	Renewable energy company	Grameen Shakti	1996-now
Guatemala	NGO	E&Co.	1996-now
Indonesia	Village cooperation (KUD)	AusAID	1997-1999
Namibia	Government	Namibian Government	1997-now

In the BELSOLAR project in the **Philippines**, the Development Bank of the Philippines (DBP) wanted to test a credit facility for development lending [Mendoza, 1996]. In this project, a church-based co-operative is the implementing agency in the field. The Saint Joseph's Credit Union (SJCU), which was created to finance farm implements of the Belance-farmers, applied for the loan from the DBP. The SJCU appointed a steering committee and a BELSOLAR Project Manager for day-to-day operations. The project was set up in the following way.
The end-user buys the indoor component (3 lamps, battery, indoor cables and switches). The outdoor component (the PV panel, support frame, outdoor cable, and the battery control unit) is financed. Loans are only available for installations that are in accordance with approved standards. If instalment payments are not made, the outdoor component is pulled out, the end-user is able to get a recharge for his solar battery down in the valley, and still use his indoor system. In a contract, the responsibilities of the end-user are spelled out. Any modification to the system without consent of the SJCU technician is considered to be tampering with the system. If there are any problems, the end-user may call upon a SJCU technician, who charges a standard service fee per visit. In addition, the servicemen are instructed by the SJCU to inspect the systems from time to time. Until the systems are completely owned by the end-user, the end-user must consult a technician for any SHS modification (adding an extra light, connecting a radio or TV, etc.)

The amount of the service fee appeared to be appropriate for a SHS in the village centre, but not sufficient for installations in more remote areas. Thus the SJCU established a variable fee structure, depending upon location.
In 2000, it was reported that none of the 100 systems are operational [Mendoza, 2000]. It was concluded that the Rural Electric Co-operatives are not necessarily the best conduits for PV based electrification in the more remote areas. It is decided that the next SHS project, in Palawan, will be organised in a different way, such that systems are owned by the local government unit.

The company Sudimara, in **Indonesia**, succeeded in selling 8000 SHS in 2.5 years [Miller, 2000]. Because 90% of the systems were sold on 4-year credit terms, cash flow became the most important constraint on sales.

In **Bangladesh**, Grameen Shakti is a renewable energy company, has introduced a soft financing scheme so people can afford a solar home system. The customers of Grameen Shakti can take loans from the Grameen Bank, which is an established micro-lender, to buy the solar home system.

In **Guatemala,** Genesis is an established micro-lender, who expanded its activities to renewables [E&Co, 2000]. This would allow for significant synergies, as their existing training and lending infrastructure were used to facilitate the services to customers interested in renewables. E&Co lent funds to Genesis on a long-term, low interest basis for establishing a revolving fund. In addition, it provided a small grant for marketing, and training to Genesis to make this established micro-lender acquainted with the potential and characteristics of renewable energy. The funding by E&Co allowed Genesis to charge low interest rates and provide a long pay-back period to its customers. Users were responsible for maintenance; no post-instalment services were contemplated.
An NRECA evaluation of the Genesis project showed that the customers were not satisfied, because the systems did not provide the services they were supposed to receive. Main causes of this failure were wrong buying policies (the cheapest systems that did not meet minimal quality standards) and the lack of technical assistance to users [Arriaza, 2000]. The project is defunct now.

In **Indonesia,** AusAID has provided funding to start a project that involves establishment of revolving credit funds for SHS, training, and partial grants for households in transmigration areas [Djojodihardjo, 1996]. Altari provides installation and training for local Village Unit Co-operative, or Koperasi Unit Desa (KUD). PT LEN manufactures the balance of systems in cooperation with Solarex.
This program capitalised on lessons learned from the earlier BANPRES program to improve the quality of technical management, financial management and communication and to improve the after-sales service.
The national government provided a subsidy on the purchase of the systems. The KUD collects the monthly fees, takes care of the maintenance of the systems, buys new batteries and keeps spare parts. The private sector takes care of training of the KUD. The consumer pays a monthly payment for new battery, and maintenance by the KUD. It is reported that there have been problems with the technical performance and the reputation of PV. Furthermore, up to now no demand for systems outside the projects has originated, probably because the users who have not been part of the project do not want to pay more for their systems than the project participants.

In **Namibia**, the Government developed a subsidised credit scheme for Solar Home Systems. The loans are provided from a revolving fund, set up by the Ministry of Mines and Energy, NORAD (Norwegian development corporation), USAID (United States' development corporation). Pay back of the loans is considered to refill the fund for new energy technology loans, but given the subsidised interest rates the fund is likely to dry up in the long run. The impact of the credit facility has been limited. Between 1997-1999 less than 400 SHS have been sold and installed. The main reasons for the limited uptake are considered the high price of SHS, the fact that SHS are not able to meet all the household energy requirements, limited awareness and bureaucratic loan procedures. Nevertheless an evaluation showed that users were generally satisfied with their SHS.

Credit for solar home systems could be an institutional model that is attractive for income groups that have a regular income but cannot afford to pay the system on cash. On a small scale, projects with high recovery rates show that credit can work. However, up to now it has not been demonstrated on a large scale what is the amount of buyers that is willing to take a loan for a non-productive product as a solar home system. Furthermore, commercial financiers are not much inclined yet to solar lending. Finally, higher quality of the installed systems in this model has not been shown in practice.

2.6 Experiences with fee-for-service

Main advantages of the fee-for-service system are the spreading of costs to the user over a long period (up to 10 years), the access of the ESCO to capital and the potential for cost reduction through economies of scale (purchase costs, transaction costs, operation and maintenance costs). Utilities are used to operate on a fee-for-service basis. However, up to now they have not been very eager to get involved in solar photovoltaics because of the high costs of rural electrification with solar PV and the unfamiliarity with this new technology which is different from grid-electrification (see for example Annex 7 Brazil). Here we discuss four recent projects (see Table 2.5), in which part of the investment costs for the systems is paid by the government. The remaining costs can be recovered from the consumer, which makes the projects attractive for commercial operation. The database contains more fee-for-service projects that are not discussed here: (Brazil) the CESP Valle do Ribeira - ECOWATT Program, (Ghana:) Kpasa off-grid rural electrification project, (Peru) PV Electrification of the forest community of San Fransisco and (Zimbabwe) Study on promotion of PV in rural electrification in Mashonaland East.

Table 2.5: Examples of Solar Home System Projects implemented as fee-for-service

Country	ESCO type	ESCO Name	Period
Tuvalu (Pacific)	co-operative company	TSECS (Tuvalu Solar Electric Co-operative Society)	1984-now
Kiribati (Pacific)	private company	SEC (Solar Energy Company of Kiribati)	1989-now
Dominican Republic	private company	SOLUZ-Dominicana	1994-now
Argentina	private utility	EJDESSA (Empresa Jujena de Sistemas Energeticos Dispersos SA)	1996-now

In **Tuvalu,** the TSECS is a locally owned company, which started to implement and manage solar PV lighting kits that were donated by USAID in 1984 (see Annex 5 and [Cabraal, 1996]). TSECS performed the same task in later donor projects (1985 by EU; 1987: French government; 1992: EU). All investment costs thus far were paid by donors, until 1995 when donor support ceased. However, all operating expenses of TSECS have been paid by income from the member fees. TSECS has a strong administrative and maintenance system. TSECS is devoted just to providing rural electrification services by PV power. All systems are visited monthly by full time, specialist trained, local employees who collect fees and check on the operation of the systems. A senior technician visits every site at least twice a year to check on the quality of the local technician's work and to solve problems beyond the local technician's capability. Fee collection is by an impartial organisation based outside the community and fees are used exclusively for the benefit of the project; a structure has been set-up for users for complaints about service and management methods or expenditures they feel are inappropriate. Furthermore, more than one size of system is available to meet varying electrical needs and financial resources of users.

The period prior to 1992 was dominated by technical problems due to the poor quality of the systems. Since 1992, satisfactory technical performance has been achieved for existing and new systems, resulting in a high level of customer satisfaction and few problems with equipment failures. In 1996, 400 members of the co-operative were electrified by solar photovoltaics, with a waiting list of nearly 200 households because of lack of capital.
However, since 1993 till now, the co-operative has management problems, because of a weak financial accountability and poor planning, leading to institutional deterioration and poor service. The Tuvalu Government has recognised this present situation and has planned to reorganise the TSECS into a rural electrification utility structure such of the SEC in Kiribati. The SEC will be discussed in the next paragraph.

In **Kiribati**, Pacific Islands, the private company SEC started in 1984 as a system supplier but decided to operate as an ESCO in 1989 (see Section 2.4 and Annex 5). Since that time, SEC has operated as a rural utility. It sets up districts, with each district of sufficient size (50-125 systems) to be serviced by a SEC field technician. The user pays an installation fee and a monthly fee to fully cover actual cost of operation, including battery replacement, and maintenance of the system. Capital costs of the system may or may not be recovered according to government subsidy policy. Every month, the field technician collects the fee and checks the equipment. Twice a year, a senior technician visits each district and audits the technician's performance. Evaluation teams from the EU (in 1998) and from Japan (in 2000) reported that SEC has been successful in both maintaining the systems and collecting the fees. There are plans to increase the number of systems.

In the **Dominican Republic,** Soluz-Dominicana has been developing a fee-for-service model since 1996 (Cabraal, 1996). In an extensive test phase with 200 customers, the model was refined. It is stated that the model is now cash flow positive with 1000 or more units (Philips 1999?). The same source mentions the following strengths of this model. SOLUZ has set-up an excellent maintenance and after-sales service on the PV systems. Collection costs are low because users must put the monthly fee in lock-boxes that are located in prominent buildings. Local, independent collection agents are rewarded when collection levels are high; they report credit problems to SOLUZ before they are serious. SOLUZ has a credible repossession program, in which non-payment leads to quick and visible removal of the system. It is mentioned that the SOLUZ model is being replicated by SOLUZ affiliates in other countries. However, it is also mentioned that the financing of the trial efforts to prove the model was made possible by the personal efforts the director of SOLUZ: entrepreneurs without the proper connections will find it hard to use this model. Unfortunately, up to now we have not been able to obtain data about the technical and financial performance of the program in the Dominican Republic.

In 1996, the Federal Government of **Argentina** started a rural electrification program based on regulated concessions (see Annex 6). The market for rural electrification is divided into two parts: 1) a market that can be served by conventional (grid) electrification and that is commercially viable and 2) a market with dispersed population that has to be served by autonomous renewable energy systems and that is not commercial now. The Provincial Government gives both markets in concession to private companies for 45-90 years. Within the concession, contracts for electrification are defined per 10-15 years.
The contracts specify the extent of the electrification and the subsidies by the Government. The concessionaire is free to define the type of systems that will be installed, as well as the way it plans to obtain user contributions. It is estimated that the federal subsidies amount to about 60% of the total costs of the rural electrification in each Province.

Since 1996, concessions for the non-commercial rural market have been granted in two provinces. In Jujuy, the private utility EJDESSA has installed about 700 SHS in a fee-for-service system. EJDESSA takes care of the supply, installation, and servicing of the SHSs. The Provincial Government of Jujuy contributes an additional subsidy. As a result, the consumer pays a monthly fee that is far below the estimated payment capacity of the users. In Salta, the ESCO that obtained the concession signed the contracts but installed no systems up to now because it underestimated the costs for installation and servicing.
We could not obtain detailed information about the experiences with the project in Jujuy. It is clear that the dissemination mechanism has not been implemented as designed, because not only the non-commercial part but also the part of the project that is commercially viable is subsidised. As a result, the financial sustainability of the approach has not been demonstrated.
However, it is stated that private companies are interested in this program for other provinces. While in the program all types of renewables can be used, it is expected that PV will be the main source for electrification, and that 80,000 solar home systems will be installed in Argentina. This dissemination mechanism project gained the interest of the World Bank and the GEF, who in November 1999 signed a agreement with the Federal Government to support the extension of the Federal Program.

We conclude that recent fee-for-service systems show opportunities to combine subsidies and market operation. However, the experience with the fee-for-service system is still limited. The projects in Tuvalu and Kiribati have demonstrated the viability of a service and maintenance scheme that was integrated in these projects. However, the main challenge for this model is to organise operation and maintenance of the systems and fee-collection in a financially sustainable way, such that user contribution covers the costs for the ESCO. This has not yet been demonstrated.

New fee-for-service projects are directed towards minimising the fee-collection costs. In **Bolivia,** the local utility CRE created a fee-for-service system with help of NRECA with hardware provided by Shell Solar Energy and subsidised by the Dutch Ministry of Development Cooperation [Hassing, 1998]. In **South Africa**, ESKOM (the national electricity utility) and Shell Solar Energy created a joint-venture to provide off-grid electricity to rural consumers in a fee-for-service system [Anon., 2000]. In both projects, households pay the user contribution using pre-paid cards. No evaluations of these projects are available up to now.

2.7 Conclusion

The following lessons have been learned about organisational models for dissemination of solar home systems:
1. All details of the model must be in order.
2. Details determine the success and failure of a project (for example, maintenance by the user seldom works).
3. Involvement of local actors has usually good results (for example, regular attendance of the SHSs by trained personal.
4. Flexibility in the implementation of a model is important (for example, the adaptation of the monthly payment to the seasonal income of the consumer).

However, the experience with complete models has not been finalised. There is no model for which is has been shown that is does not work. There is not one best model: the choice for a model and the precise way it is set up depends on the institutional, legal, socio-economic and cultural conditions in the country.
The main bottlenecks per model:
- cash sale: the availability of consumer capital for the desired service;
- credit: high administrative cost and access to credit schemes generally limited to high income households;
- fee-for-service: high fee-collection and servicing cost, cheap fee collection mechanism and (risk of) lack of user care because user doesn’t own the system

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3. FINANCIAL EVALUATION

SHS have been considered an economically viable alternative to grid electrification in remote areas. This is based on a long term view in which the costs of a SHS are spread over its lifetime. However, for the potential end-users in developing countries, the required short term initial cash outlay is more important in his or her purchase decision than the actual price of a SHS. Choices have to be made between recurrent monthly expenditures of between US$ 5-15 per month for conventional energy sources such as candles, paraffin and batteries and a capital investment of about US$ 700 for a 50 Wp SHS.

Due to prevalence of other pressing needs that require an immediate expenditure, but also because of generally high inflation rate, savings in most developing countries are low. Therefore, only few people are able to collect a sum of US$ 700 without some sort of finance.

Even when commercial/conventional finance mechanisms allow the potential user to overcome this initial cost barrier, experiences show that dissemination of SHS in the poorer rural areas of these countries remain limited. To gain access to finance generally requires a regular income. Many rural dwellers living from subsistence farming or from smaller land holdings can not access these mechanisms.

There have been several initiatives with innovative financing mechanisms to circumvent the problems experienced with the more traditional financing schemes. Example are: loans at subsidised interest rates and longer repayment periods, the provision of guarantees to compensate for the lack of collateral, and group loan schemes for those without regular income.

In this sections the financial aspects of the dissemination of SHS will be assessed. First, the cost structure of SHS will be examined and compared regionally. Next, different SHS finance modes and their impact, strong and weak points will be analysed.

3.1 The cost of SHS

In the table below some examples are given - derived from the ECN/NREL database - of the cost of a ‘standard’ SHS system, consisting of 45-55 Wp panel, a 70-110 Ah battery, a battery regulator, 3-4 lights, and cabling and mounting material.

Table 3.1: Prices of SHS (US$/Wp)

country	**Year**	**indicative system price (US$) / Wp**	**note**
Dominican Republic	‘89-‘91	15	
Brazil	‘94-‘95	11-15	
Bolivia	‘95?	12	
Peru	‘95	11-15	
Bangladesh	‘93-‘97	16	
Philippines	‘93-‘94	15	
Ghana	‘98	14	
Namibia	’97 - ‘99	22	incl. installation
Swaziland	’97 - ‘99	17	incl. installation
Botswana	’97 - ‘99	16	
South Africa	‘95- ‘96	10	cost price
Zimbabwe	‘97	17	incl. installation

The figures above only give some rough guidelines on retail prices. The system price in some cases only refers to the cost of the hardware in bulk, whereas in others a retail margin of 20-30% is included. Also some system prices include installation cost and some don't. A range of US$ 10-22 / Wp has been found. The relatively high price in Namibia is to some extent accounted for by relatively high transport cost. Interviews with key players in the field also point to the Government's bidding process for SHS as a major reason for the prevailing high prices of SHS. Only a handful of suppliers are selected to supply SHS under the Government scheme that caters for subsidised finance to end-users. In this case, the introduction of a subsidised scheme has disrupted a competitive market environment and has forced independent PV suppliers outside the Government project to step away from the SHS market.

The underlying factors of the price differences can not be fully established at this stage. To a certain extent the difference may be due to differences in duties and tax structures, which in turn may be related to time or geography. In West Africa e.g. high duties and taxes prevail on solar equipment, whereas in most countries in Southern Africa, solar equipment is exempted from duties. This however is a rather recent phenomenon. In the early nineties, the combined duties and taxes in Southern Africa were also considerable: Zimbabwe 49%, Mozambique 49%, Malawi 43%., Swaziland 38%, Zambia 38%, Namibia 27% [Bogach et al, 1992]

Table 3.2: Tax and duties on solar equipment

country	**duties and taxes**
Dominican Republic	no import duties on panels, 100% duties on deep cycle batteries
Philippines	no import duties or value added tax on panels and components
Indonesia	no import duties
Gambia	30.9% import duties, 10% sales tax
Burkina Faso	56% import duties, 20% sales tax
Ghana	10% import duties, 15% VAT
Swaziland	no import duties on panels, sales tax 12% no duties on batteries (imported from RSA = custom union)
Botswana	no duties or sales tax on panels
South Africa	no import duties on panels, sales tax 14% on panels and components, batteries locally manufactured
Zimbabwe	no duties on modules, 15% sales tax on panels and components.

Source: NREL/ECN Database

The generally prevailing perception is that the price of SHS is decreasing. However, for the data collected in the database, it is not possible to confirm the expected reduction in the price of PV hardware. The above indicates that if any price decrease of PV hardware has occurred in SADC countries this decrease might be closely related to a decrease in taxes and duties rather than to a decrease in the cost price.

Although the focus in most cost comparisons have been on solar panels, which generally constitutes the main price component of a SHS, very little attention is paid to the contribution of the battery in the total costs of a system. On a life cycle basis the battery costs exceed those of the solar panel by far. This becomes clear if the following example is taken into consideration:

- a lifetime of a solar panel of 20 years;
- a price of US$ 300 for a 50Wp solar panel;
- a life time of battery of 3 years;
- a price of US$ 100 for a deep cycle battery (90-100 Ah).

The total cost of the battery over the total lifetime of the system would be about 7 x US$100 and hence weighs considerably higher than the panel cost. The share of the battery in the total system price increases even further for smaller systems (< 20 Wp).

In most projects the cost of batteries, and thus the need for financing battery expenditures, is not considered. The consequences are reflected in for example the projects in Mexico and Guatemala (Zacapa) where the (financial) scope for battery replacement is lacking and hence many systems do not or hardly perform. A positive example is the NRECA-approach (Guatemala), where communities have created a solar fund that will be used to replace balance of system components. The small monthly amounts that are contributed by the solar committee members are calculated in such a way that replacement can be made on time. For such a fund to function well, the administrators need to be highly trusted and frequently controlled by the committee members. If this is not the case, the fund is likely to fail. The projects in Bolivia (Bolivian High Plateau) and Tuvalu (Pacific) are examples of the latter, where mismanagement, lack of financial accountability and corruption have negatively effected the project progress.

3.2 Financing of SHS

The lack of appropriate finance is often quoted as the main bottleneck for widespread dissemination. If the price examples above are related to income levels in developing countries, it is clear that the capital cost of a SHS goes beyond the financial capability of many. E.g. in many developing countries the price of a standard SHS is equivalent to 4 to 6 times the monthly salary of a rural teacher. In the developed countries - taking into account the level of income of a low to middle income household - the relative cost impact would be comparable to the purchase of a standard car. Also in developed countries, many people need finance for a purchase of this financial magnitude.

Looking at the world-wide experiences with different forms of finance, four major institutional models (delivery modes) can be distinguished:
1) donation delivery mode;
2) credit delivery mode;
3) cash delivery mode;
4) fee for service delivery mode.

3.2.1 Donations

The database provides various examples of projects using the ‘donation’ delivery mode, which implies that the donor provides the hardware for free or almost for free. The major problems encountered with donations - especially among the earlier projects - are that the users in general have not been properly involved and as such do not feel responsible for maintenance of the systems. Most of the donations or subsidies are limited to the hardware only. With reference to the section on technical performance, SHS do need maintenance! Batteries have to be replaced after 1-3 years, just like light bulbs and fittings and - to a less extent - regulators. If SHS are given away to people who either can not afford it or don’t feel responsible for it, the donation will be wasted if no arrangements are being made for maintenance.

The example of Mexico (see Annex 8), where SHS have been donated on a fairly large scale, shows nevertheless that if users are properly involved and adequate maintenance services are provided, dissemination through donations can be successful in terms of technical performance and user satisfaction.

Table 3.3: Examples of heavily subsidised schemes

	initial fee	monthly fees	notes
Indonesia	US$ 25	US$ 3 over 10 years	less than 50% cost recovery, drain on Government budget
Ghana	US$ 50	US$ 3 over 5 years	12% default rate and after 5 years, user owns system, but maintenance neglected. Many of these SHS do not work.
Tunisia	0	US$ 5.20 p.m.	hardware 100% subsidised, operational fee only. People refuse to pay maintenance, because of 'free gift'. After project stopped, people could nevertheless afford US$ 208 for grid connection.
South Africa	5% of hardware	0	hardware 95% subsidised. 5% paid by farmer and/or farm workers. Farmer/farm worker responsible for maintenance and replacements. One third of SHS doesn't work any more. More than half the SHS showed technical problems.
Guatemala	0	0	100 % subsidised, but replacement of battery too expensive: 43% of systems do not work anymore.
Bolivia	US$ 80	US$ 1	hardware 100% subsidised, problems with collection of maintenance fee and mismanagement of funds

Source: NREL/ECN data base

3.2.2 Credit delivery mode

The generally disappointing experiences with donations on the one hand and the need for finance on the other has resulted in the search for other more structural delivery modes. The provision of credit has for some time been considered the answer for widespread dissemination. The database provides many examples of such credit schemes. The overall impression of these schemes is that they work reasonably well, in case good quality systems have been installed. The repayment discipline is strongly related to the technical performance of the system. If the system doesn't work, people stop their loan repayments.

A major limitation of credit facilities is that access is generally restricted to those people with regular jobs and as such are only within reach of the middle/high income groups. Examples of various 'soft' credit schemes in Southern Africa show a penetration rate of not more than a few hundreds of systems in 3 years time.

Table 3.4: Examples of SHS credit schemes in Southern Africa

	Namibia	**Botswana**	**Swaziland**	**Zimbabwe**
Price 45-50 W_p /4 lights (SHS)	US$ 1095	US$ 800	US$ 700	US$ 750
deposit	20%	15%	25 %	25%
interest	5%	14%	22%	15% p.a. (fixed)
max. repayment period	60 months	36 months	36 months	36 months
Transport cost	Included in price	US$ 0.26/km	included in price	US$ 0.37/km
project start	1997	1997	1997	1996
no. of installations	ca. 350	ca. 280	ca. 350	ca. 100
seed finance	Ca. US$ 650,000	ca. US$ 900,000	ca. US$ 150,000	ca. US$ 70,000
source of finance	Namibian Government, NORAD, USAID	Botswana Government	Triodos Bank, Hivos and Doen Foundation	UNDP/GEF (NGO mode)
repayment of seed money	repayments flow back to revolving fund	repayments flow back to revolving fund	repayment at 14% interest	repayment at 0% interest and deduction of maintenance cost

The table 3.4 indicates that neither the level of seed finance nor the level of interest rate seems to make a huge impact on the level of penetration. High interest rates and relatively low amounts of seed finance in Swaziland have generated similar results as highly subsidised schemes such as the one in Namibia and Botswana. A possible explanation of the difference may be that in Swaziland, the project was run independently from Government with only a limited number of players involved. In the other countries, bureaucratic, inefficient organisation has absorbed more money than would have been necessary.

In all the examples above the credit schemes have been established with the support of Government or donor organisations. Also the other examples in the database show that most credit facility are somehow linked to external parties, e.g. AusAid in Indonesia, the World Bank in India, Enersol in Dominican Republic and Honduras, providing either the seed finance for establishing a revolving fund or financial guarantees of generally up to 100%. Without such support local banks and other financing institutions are often reluctant to provide loans for non-productive investments to the rural population, which they generally perceive as a 'non-bankable' group. This perception is based on difficult and costly credit appraisal procedures, relatively high administrative cost - due to small loans, and frequent repayments - and lack of collateral.
And true, the data base provide several examples that confirm these difficulties related to 'rural finance':

- The Government project in the Philippines, involving ca. 50 SHS installed on a credit basis. After 3 years the repayments discipline drastically deteriorated and project had to stop, because the cost of collecting exceeded the revenues. The deterioration in repayment is closely related to technical problems with the system. It again indicates the importance of proper maintenance arrangements.
- The Government program in Thailand where ca. 3.5 kWp has been installed, with farmers being the major target group. Revenue collection turned out to be extremely difficult.

During the day farmers are generally in the fields making the physical collection difficult. Also when crops fail and not enough income can be generated from the harvest a social problem arises to repossess SHS of impoverished families.
- In Tunisia the set up of credit schemes or payment in terms is very difficult because Tunisian Law allows only police to repossess SHS in case of defaulting.

Despite the difficulties, there are also examples where credit schemes do work. A crucial element of a proper function credit scheme is close co-operation of and co-ordination between financial and technical partners. SHS need to work for the scheme to be successful. This could be considered one of the merits of the credit delivery mode. End-users have some protection against the supply of low quality hardware or lack of after sales service: they can stop their repayments if they are not satisfied. Suppliers or external financiers will therefore make sure that good quality equipment and adequate after sales services are being provided to avoid the risks of non-payment.
Finding the right partners may however be a time consuming and costly procedure, not everybody is prepared to undertake. For example in Kenya it took almost 2 years to identify the right partners and to establish a good procedure for a feasible financing mechanism for solar electric systems for use in households [World Bank, 1999a].

The fact remains that most credit facilities leave out those without regular income, and hence excluding 60 to 85% of the population. A credit delivery mode will therefore have a limited outreach. If the objective is to reach the rural majority, alternative approaches are required.

Various attempts have been made to cater for those without regular employment. For example group loan schemes have been tried in various parts of the world. It seems, however, that such schemes are strongly related to culture. In Latin America group loans through co-operatives have functioned very well, contrary to individual loan schemes. A pre-condition for this approach is the prior (long-term) existence of co-operatives, and thus the interdependence of its members. This interdependence between the members assures a mutual control and a moral obligation to meet the terms of the credit agreement. An example is the COMARCA case in Honduras (CADETT).

In Southern Africa group schemes seldom work. They have been tried not only for SHS but also for other purposes, but group formation seems difficult to achieve. Due to the scattered nature of the settlements (there is no village structure in Southern Africa), people tend to rely upon themselves and lack the social coherency that characterises many other parts of the world. The Maphephethe SHS project in South Africa is an example of such a group loan initiative that failed to materialise [Cawood, 1998].

3.2.3 Cash Delivery Mode

In the absence of a solar demonstration or development program or in some cases parallel to such programs a few examples exist of the development of a healthy private market for SHS.
The notable example is Kenya, where at present some 150,000 systems have been sold commercially. Similarly in Zimbabwe, some 80,000 SHS have been installed to date [World Bank, 2000]. About 10,000 systems have been installed under the GEF funded (US$ 7 million) project. The remaining 70,000 have mainly been sold on purely commercial terms by the private sector. A more direct comparison: whereas the GEF installation rate amounted to about 100 installations per month, the private sector managed to install 200 to 300 per month outside the GEF project without subsidy or the like [APTECH, 1995]. It is not unlikely that a similar situation prevails in other developing countries, but actual data are not available at present. This is clearly an issue that deserves more investigation.

The key to success in the above mentioned cases is the supply of small PV panels (10-15 Wp). For example in Zimbabwe, the GEF project provided mainly 40-50 SHS at subsidised credit terms. The private sector on the other hand filled the niche for small panels, mainly on a cash basis.

The examples in Zimbabwe and Kenya show that people tend to go for a modular approach, viz. starting small and gradually expanding the system in line with the availability of cash. A household generally starts with a television. This television is powered by a car battery, which in turn is charged at a charging station in a nearby town.

The present use of car batteries is significant. ESMAP financed surveys in Chad, Kenya, Uganda, and Zimbabwe showed that these numbers are surprisingly high. In Dourbali, Chad, a trading village with a weekly market about 80 km from the capital, 30% of households were found to use a car battery. In Uganda, some 10% of households in peri-urban areas and in areas surrounding rural trading centres are already using a car battery, which corresponds to about 4.5% of all rural households in Uganda. In Zimbabwe, ZESA (the electricity utility) and ESMAP found that the number of battery using households could be as high as 20% of all rural households (or 230,000). In addition, some 85,000 peri-urban batteries are estimated to be in use. In Kenya there are an estimated 2% - 5% of all rural and peri-urban households with a car battery (or 70,000 – 150,000) [Hankins et al, 1998].

To overcome the drudgery of carrying the battery to and from the charging station, these households may buy a solar panel to charge the battery. As time goes by the system may be expanded with another panel and some lights.

If the present car battery using households are considered a potential market for solar panels, the above figures indicate that this potential is huge. However, the present ‘standard 50 Wp system’ may need to be scaled down. A major disadvantage of the presently installed small sized system is their generally sub-optimal performance. In Kenya about one third of the systems are technically imperfect, due to a mixed quality of components, incorrect installation and maintenance. To assist the market development of smaller systems, more attention and support should be focused on optimising these smaller systems (see also technical section) rather than on financing them.

3.2.4 Fee-for-service

Another approach to overcome the financial hurdle of SHS is the rental of SHS, also known as fee for service or lease of SHS. The concept of a rental scheme is similar to the one of a grid connection: people pay primarily for the service rendered viz. energy delivered and not (directly) for the infrastructure to provide the service. Similarly, with a SHS rental scheme, people pay for the continuous use of a SHS. The service provider will spread the depreciation cost of the system over the lifetime of the system and projected maintenance costs can be evenly included in the monthly rental fee. For the end-user therefore the monthly cash outlay becomes fixed and no unpleasant financial surprises arise when a system fails. Under this delivery mode the financial threshold will be substantially lower than e.g. under a cash or credit mode and therefore more people could be reached.

The scheme has amongst other been applied in Argentina (see also Annex 6), South Africa and has recently started in Zimbabwe. In Argentina, where rural electrification is stimulated by Government through a concessionaire system, a private company has embarked on a fee for service systems using prepaid cards. The cards are based on time and do not depend on consumption. A similar system is used in South Africa, where Shell Solar and South Africa’s electricity utility ESKOM, launched their joint scheme in February 1999. After a slow start the number of installations accelerated and at the time of writing the first phase can successfully be closed with the realisation of 6000 installations.
Although it is too early to assess the impact, a rental scheme clearly has some advantages over credit or cash schemes. It lowers the up-front cost for the end-user, allows for bulk purchases of the hardware and hence reductions in capital costs and it allows for ‘controlled and qualified’

installation and maintenance, thus improving the technical performance of the systems. A negative aspect of a rental system is that users may be rather careless with the system, knowing that maintenance and repairs are for free.
Also the problem associated to the collection of the recurrent service fees remains. In the more recent projects like the Shell/Eskom one, one has tried to overcome this problem by using a pre-payment device. The user has to buy a token and only by inserting a valid token, the system will start operating. Such a system clearly prevents use without payment, but it doesn't prevent the system from standing idle due to temporary cash shortages. In the South African case repossession in theory take place after two consequent months of non-payment. Whether this is sustainable in a 'poor' rural setting is questionable. Similarly, if the user skips a month's payment, he or she first has to 'catch up' with payment and hence still pays for the month(s) the system has been 'idle'. From a commercial point of view such an approach makes sense, but it may result in unnecessary high repossession rates and hence costs.

3.3 A comparison of different delivery modes

After the discussion about the various delivery modes, the question 'which delivery mode is the best' remains. A straightforward answer can not be given. It seems that there are no universal solutions. What works in one country or for one target group doesn't necessary work in a different setting.
Recognising that each case may require its own tailor made approach, the table below tries to summarise the three main delivery mode against the following criteria:
- Affordability: is the delivery mode affordable for the end-user or not?
- Maintenance and repairs: how does the delivery mode affect maintenance and repairs?
- User-behaviour: how does the delivery mode influence the user behaviour?
- Scale: does the delivery mode lend itself for widespread dissemination?

Table 3.5: Comparison of the different institutional models

	Donations	**Cash**	**Credit**	**fee for service**
Affordability	High, due to low up-front costs	Limited to higher income groups	limited to higher income groups	depends on what the fee intends to cover
Maintenance and repair service	Usually, service completely dependent on user	Service completely dependent on user	service generally stops after repayment of loan	good service required to ascertain payment of fees
End-user behaviour	Difficult to get users involved	Generally good, but depends on availability of spare parts and money	generally good, but depends on availability of spare parts and money	users tend to be less careful, since repair and maintenance is for free
Scale	Limited to (government and donor) budgets	high potential for small system	limited	depends on fee and cost of organisation

Affordability
Compared to credit or cash scheme, a rental scheme can spread the cost of the hardware plus maintenance out over a longer period of time thereby reducing the monthly burden, whereas no initial capital outlay is required. Moreover, given the bulk purchases of the hardware, actual system prices will be lower than following the normal whole sale, retail distribution channels. Fee for service requires however a complex organisational set up with high overhead cost. If these costs are to be reflected in the monthly rental fee, the fee would become too high. Hence

affordability will depend on whether the fee is supposed to cover all costs or is subsidised (see cases in Argentina, Brazil). The present trend within the fee for service delivery mode is the search for more cost effective ways to collect the revenues. Examples are the prepayment cards, or other forms of token operated systems such as in Argentina and South Africa.

Maintenance and repair
Under a rental scheme it is in the interest of the service providers to keep the systems in good shape. In practice however, the organisational set up of a proper service structure seems very costly and in many cases involves some sort of support to make it happen. In Brazil, utilities lost all interest after they were privatised; in Argentina, commercially interesting concessions are now coupled to the electrification of the dispersed rural markets, to make sure that commercial concessionaires deliver good services.
Under a credit scheme this applies only during the repayment period. After that it is up to the users to maintain his or her system. Experiences from the field have shown that end-users tend to buy the cheapest possible replacement options (e.g. car batteries instead of deep cycle batteries, low quality lights, bypassing of regulators once they are worn out). This may seriously affect the performance of the systems.
Under the cash delivery mode, the quality of the installations may be a problem right from the start. Due to the purchase of badly matching components and by improper installations, a sub-optimal performance of the system is more common than not.

User behaviour
It has already been mentioned that ownership contributes to better care for one’s systems. But, the effectiveness of their involvement depends to a great extent on their level of knowledge (training, see Genesis and Zacapa examples from Guatemala) and the availability of good quality systems, spare parts and appropriate distribution mechanisms.

Scale
A rental scheme requires a well-developed infrastructure, including ware housing, retail outlets to purchase tokens or collect the service charge, dedicated technicians. The set up of the infrastructure, therefore only become viable if the demand is high enough and rather concentrated. Where no infrastructure exists yet, the scale is likely to remain small.
With a credit and cash schemes the scale very much depends on income levels and real demand. If people are not interested in or can not afford a SHS the scale of operations will remain small! The cases seem to suggest that credit schemes are able to capture only a limited market segment, viz. the higher income groups with regular jobs. This is because the systems provided under a credit scheme are often relatively large and expensive. The examples of Kenya and Zimbabwe seem to suggest that small system are more in line with what people are prepared to pay for a basic electricity supply.

3.4 The role of subsidies

After the discussion of various delivery modes the final question of subsidies remains. Are subsidies necessary to disseminate SHS or can the private market handle it independently?
To answer this question the type and objectives of subsidies have to be defined. There are basically three types of subsidy:

1) subsidies aimed at supporting the creation of a commercial market, e.g. loans to small entrepreneurs, provision of training, creation of awareness;
2) subsidies with a direct social objective of electrifying the poor, e.g. soft loans or direct subsidies on systems;
3) subsidies to stimulate existing commercial companies to enter into otherwise uninteresting markets.

The general impression from the projects in the database is that the first type of subsidy seems necessary to spark the development into a (semi) commercial market for SHS. However, very

few projects - so far - have reached this stage of full commercialisation. On the other hand the few commercial successes, such as Kenya and Zimbabwe, have materialised without subsidy. Strange is the fact that SHS market developments of such a significant scale only occurred in a limited number of countries.
A possible explanation may be the role of the ‘extended family’ in Africa. The existence of the ‘extended family’ implies strong social and economic obligations to the next of kin. This may give rise to the purchase of hardware by the family members that earn higher incomes, and the direct or indirect use of this income by their kin in the poorer rural areas. In fact, we can see this as a direct form of subsidy, avoiding the state as an intermediary. Instead of paying taxes, Africans developed an alternative system of mutual (social) support, which is the extended family. Surveys among SHS users in Swaziland and Zimbabwe show that about one third of the systems used in rural areas were bought by those members of the family who normally stay in town (viz. their place of work). [Lasschuit, 1999, Cloin, 1998]
In the absence of such tight social relationship, a commercial market development for SHS may be difficult to achieve.

The second form of subsidy notably a subsidised credit scheme seems to have some merits. With a subsidised credit scheme the end-user can stop the loan repayments if the system is not working properly and as such can indirectly force the supplier to provide quality hardware and services - at least for the period of the credit. Credit facilities could help widening the market by lowering the upfront cost, but the extent to which this is possible seems limited. Credit facilities are generally accessible to the higher income groups only and there are many examples in the database where this market segment has not been sufficient for the development of a commercial market. To really electrify the rural poor, a credit facility cannot be the answer.

The last form of subsidy - aimed at commercial companies to enter into otherwise uninteresting markets - is widely applied in Latin America. Here utilities and governments often make use of concessions to companies for the installation of thousands of SHS in rural areas.
A different way of using concessions was applied by ESMAP and the local Government in the Comoros [World Bank, 1999b]. Here a private company was given various time-bound benefits to trigger the commercial development of the solar market. These included a three-year grace period for taxes and duties. Also the Government pledged that it would grant the firm contracts for all public projects dealing with solar energy during a two-year period and to support the activities of the company the Government launched a solar awareness campaign. In addition a revolving fund of US$ 100,000 was made available for the exclusive use of the firm for a period of 2 years. The fund was managed by the Government, which placed an order for demonstration equipment from the selected firm for the full amount. Any amounts recovered were to be reinvested in more equipment through follow up orders to be made by Government.

Clearly, concessions and other preferential treatment have the inherent danger of creating monopolies. Given the fact that without such concession no activity may have come from the ground at all and that such preferential treatments are only temporary, this kind of subsidy seem to sort some effect. In the case of Comoros, the company managed to install 16 kW of modules during the first 2 years of operation and invested a similar amount from its own resources as was put in by the project. Although the company has established itself firmly, and further market development looks promising, it is still too early to project what will happen after the concession period ends and the firm has to operate on purely commercial terms.

3.5 Conclusion

The examples in the data base show that contrary to generally prevailing perception, the price of solar home systems has not decreased over time. Even if those cases were panel prices have dropped or remained constant, this has not been related to reductions in production cost, but to reductions in import duties and taxes.

A standard solar home system of 50Wp currently costs about US$ 700. This is equivalent to 4-6 times the monthly income of relative well-paid salaried rural dweller, such as teachers and nurses. Hence, for the systems to become affordable some sort of finance will be needed .

Conventional finance mechanisms don't seem appropriate for the rural end-users. The PV technology is not well known and the rural end-users are not considered creditworthy. Moreover small loans to rural people are considered too costly to administer.

As a result, many solar implementation projects include a finance component. This varies from donations, to credit facilities and rental schemes. All these schemes have shown to have pros and cons. Donations score high on affordability, but generally lack user commitment to maintain the systems. Cash sales score low on affordability, but given that the system is the user's own choice he or she will generally look after the system well. The bad side of cash sales is that the user is tempted to go for inferior, cheap quality components and replacements, resulting in high failure rates. Credit schemes are generally limited to the higher income groups and have high administration cost. For the period of the credit users can generally enforce proper maintenance of the system. If this service is not provided, they simply stop repaying their loan. Similarly, with a fee for service scheme the end-users are guaranteed of a lifetime service. But, given the lack of ownership, end-user behaviour may not be optimal.

The justification of subsidies for PV systems remains an issue for debate. There are examples of subsidies that have been necessary to spark the development into a (semi) commercial market for PV systems. But even without subsidies a commercial PV market has emerged in a limited number of cases. Subsidised loans only seem to benefit those who are already better off and are therefore questionable. Concessions and other preferential treatments to existing companies to enter into otherwise uninteresting markets seem to have the inherent danger of creating monopolies. Given that without such concessions no activities may take place at all, such preferential treatment may have some merits.

3.6 References

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4. EVALUATION OF TECHNICAL FINDINGS

A sufficiently high quality of solar photovoltaic system components is essential for a successful introduction of solar electricity for household applications. Quality has been defined here as the extent to which the product meets the user's expectations. Low-quality products always fail early or never meet user-requirements. Quality is closely linked to other aspects of solar home system dissemination. When not used properly and in absence of maintenance, even high quality PV products can fail in a short time. Frequent failures, even of small and cheap components as fluorescent tubes will cause user-dissatisfaction that will quickly lead to reduced incentives to continue repaying the fees if the system was not sold for cash. Well-designed systems with sufficient product quality are essential to make credit schemes or fee-for-service systems financially viable.

In the rest of this chapter a number of technical issues will be discussed. It starts with a description of the types of systems installed. A major part of the chapter is dealing with quality aspects and lifetime of the different components. This is followed by a short discussion of the problems around local production of solar home system components.

4.1 Specifications of installed systems

4.1.1 System dimensioning of PV-modules and other system components

In 39 cases in the database the module power of the PV systems were given. We obtained a distribution of PV module power as shown in figure 4.1. It shows a peak in the range of 45 to 54 Wp, consisting mainly of 50 Wp systems. It is clear that activities with small amorphous silicon modules are seriously underrepresented, with only a single case in the database.

Loads that were used with solar home systems of different sizes, were found to differ widely. Most solar home systems are used for lighting, although in many cases the possibility to add a radio or television set was an important incentive for buying. Also the smaller system sizes can be used for watching television, provided that small, efficient television sets are used. Use of television sets with 12 Wp modules have been reported in Kenya. However, 35-55 Wp modules are required if a few hours of television watching is combined with lighting. Sometimes, the 35-55 Wp modules were found not be sufficient as was the case in **Indonesia**. Power rating of the modules in the Banpres project was 45 to 48 Wp, and 70 Ah (C10) open cell lead acid batteries were used. [Wade, 1994]. A survey conducted five years after installation showed that: "where only lights are used with the system, the users seem to be relatively satisfied with the performance of the system. With additional appliances, such as a TV set, the expectations are not met anymore. Users complain that they sit in the dark to watch TV or use the traditional kerosene lamps. Many use additional car batteries for the TV, which are charged from another source of electricity, e.g. a communal diesel generator for about US$ 0.33 a week." [Fitriani et al, 1998].

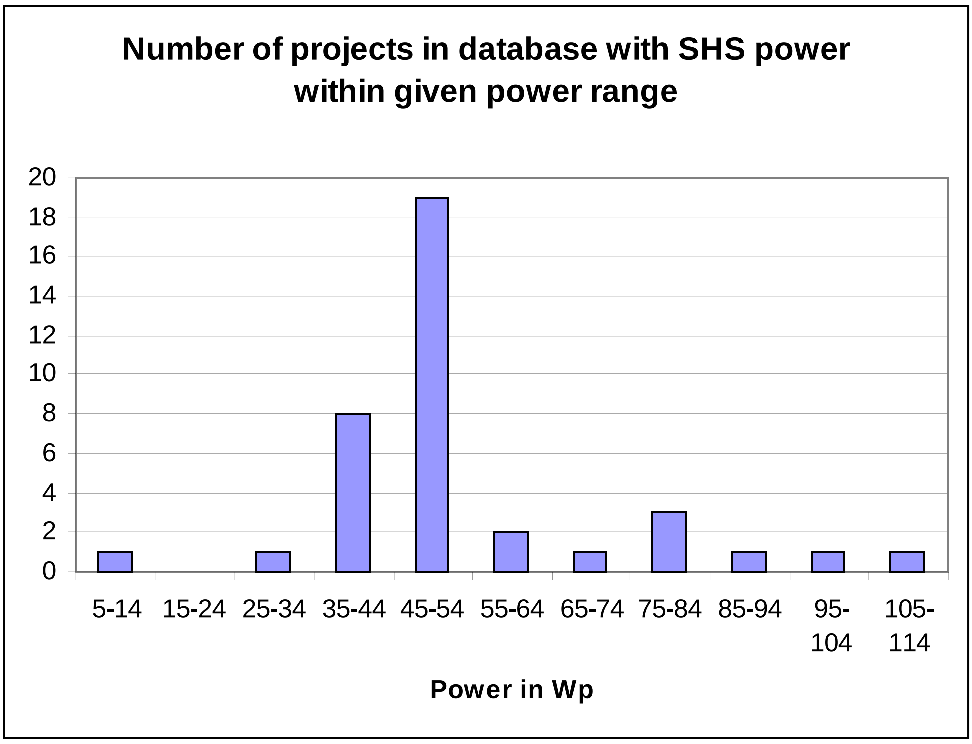

Figure 4.1 Distribution of module power for the solar home systems in the database

In some of the commercial markets there is a trend towards increasingly smaller sizes of the system components, especially the modules. Smaller and cheaper systems mean increased affordability in markets that rely heavily on cash sales. This trend is not detected in government- and donor sponsored markets where the up-front and recurrent costs for the users are much smaller.

ESMAP surveys in **Kenya** showed that households favoured small components as these became available. "When the amorphous 10-12 Watt module was introduced, this quickly became the norm. The same happened when the 60 Ah solar battery (with thicker plates and more fluid) was introduced and people abandoned the 75 Ah battery." [Hankins et al., 1998]

In the government programme in **Tunisia** an opposite development exists in the direction of increasing PV-module capacities. This is probably related to the higher seasonal variations in insolation compared to tropical countries, requiring large module sizes to meet electricity demand in winter. Module power as specified in the tender documents increased from 70 Wp in the first stage of the government programme to 100/106 Wp in the subsequent stages. Still more important, battery capacity doubled from 90 Ah to 180 Ah. The type of battery also changed, from solar batteries with thick flat plates to tubular batteries as standard. As a result of both changes, prices of the batteries used tripled. A system with a 70 Wp module produces 150-200 Wh per day of available energy, which is sufficient to cover the basic electricity consumption of a rural isolated household in Tunisia. Therefore, the decision to increase module power to 100/106 Wp can be reconsidered in future tenders. According to computer simulations, an optimal capacity of the battery for a 70 Wp system is 110 Ah. [AME, 1999]

4.1.2 Module orientation and shading

With an optimal orientation and tilt angle of the module, the highest daily or annual yield can be achieved. In most cases this is determined by the orientation of the roof. Near the equator the orientation is often not very important for the annual yield. In some cases shading of modules has been noted that can seriously decrease electricity yields. No information could be obtained on the potential losses due to sub-optimal orientation and shading.

“In the Sundarbans project in **India**, out of 46 modules, 30 were facing true south. 11 were facing Southwest, 3 in Southeast and 2 were facing east direction. Most of the modules are installed upon thatched roofs, which have sunk over the period and have been deformed. Modules over such roofs have also lost their original directions. In one case, the owner has shifted the module to the east-facing roof that is in the front portion of the house. The original installation, which was on the south-facing roof in the back portion of the house, was not found safe against theft. The owner is aware of the loss of power, but safety of the module is his priority over its utilisation. Alternate arrangement such as installation on a pole in front of the house has been discussed with him. In some cases, due to construction, remodelling the house, modules have been reinstalled. South facing direction was nor strictly adhered to in such cases. Shadowing by some nearby structure and by growing trees was also observed.” [TERI, 2000]

4.2 Quality and lifetime of different solar home system components

Only in a few projects some limited information is provided on what share of the installed systems are really working. There are projects that claim that all or almost all systems operate, while others mention 100% failure. Most activities for which data could be obtained showed that on average around three-quarters of the systems still operate relatively well. This is a very crude estimate, since it is basically impossible to make good comparisons based on the currently available data. Each source has a different interpretation regarding the status of the system. Furthermore, large differences exist in installation dates of systems in different countries, and sometimes even within one country.

Kenya
One of the first who reported on the issue of system functioning were Acker and Kammen, based on a survey of 44 solar home systems in Kenya. Of all the systems, 10% was inoperational and 30% were partly operational. A clear distinction could be made in performance of small (<25 Wp) and large systems. The small systems, relying on amorphous modules, were less likely to perform well. 13% of the small systems were inoperational, and 40% were partly operational. Of the larger systems, only 8% was inoperational and 25% partly operational. [Acker, 1996]

In a survey of 91 solar home systems of different sizes (12-60 Wp, 75 crystalline, 16 amorphous) in Kenya, it was observed that 77% were functioning well and had no reported problems, while 7% reported more than one problem. No problems with the modules occurred. 6% of the systems had charge controller problems, and 21% had a failed battery. One or more lights were not functioning in 12% of the systems. Main problem with the lights was blackening of the PL tubes. The manufacturer replaced all the tubes as part of the service contract.

Smaller systems tend to have more problems with the batteries. About 50% of the systems with power of 24 Wp or less need battery replacement. This is in contrast with 18% of the systems in the range of 30 to 80 Wp. [Hankins, 2000]

India
Recent surveys for the Sundarbans region project in India show very high performance levels after over two years of use. 98% of the systems surveyed were still in use. Two of the 152 modules have been stolen, and two batteries were being replaced. 3% of the charge regulators were not functioning, and an additional 2.5% had problems with the indicators. All batteries were found to be in good condition (defined as Voc>12.12 Volt, equivalent to a state of charge higher than 25%). Two months earlier the two-year guarantee period ended. Most of the replacements were prompt and without any cost to the users [TERI, 2000].

Mexico

In an unpublished note sent to us by Mr. Jorge Huacuz, a summary is provided of the current status in Mexico:

‘During the years 1998 and 1999, a field survey was carried out by researchers of the Electrical Research Institute of Mexico with financing from the Mexican Federal Commission of Electricity. The purpose of the survey was to determine the physical and operational condition of solar home systems installed in a large number of rural communities in Mexico during the previous years. The degree of user’s satisfaction and the existence of other project sustainability elements, such as after-sales services and availability of spare parts and components were also surveyed. This note presents some overall preliminary results on the physical and operational condition only, of a sample of 1,743 solar home systems. Surveyed systems included equipment of different manufacturers, installed in different years, and located in a variety of physical and socio-cultural environments. Hence, results included in this note are only indicative of the whole scenario. Further analysis is necessary for the correct interpretation of these results. The survey was carried out using a methodology previously developed at the electrical research Institute of Mexico.

Figure 4.2 shows the overall result, which indicates that most systems are still in good or very good operational condition. Figure 4.3 gives the percentage distribution of the main elements of failure. As it is shown, batteries and lamps are the weakest elements of the solar home systems. Figure 4.4 focuses on the condition of the 2,026 batteries corresponding to the solar home systems surveyed. The important message here is that more than half of the batteries are not in an acceptable operational condition.

Analysis of the data banks from the field survey is in progress. Results will be published in due time.’ [Huacuz et al, 2000][2]

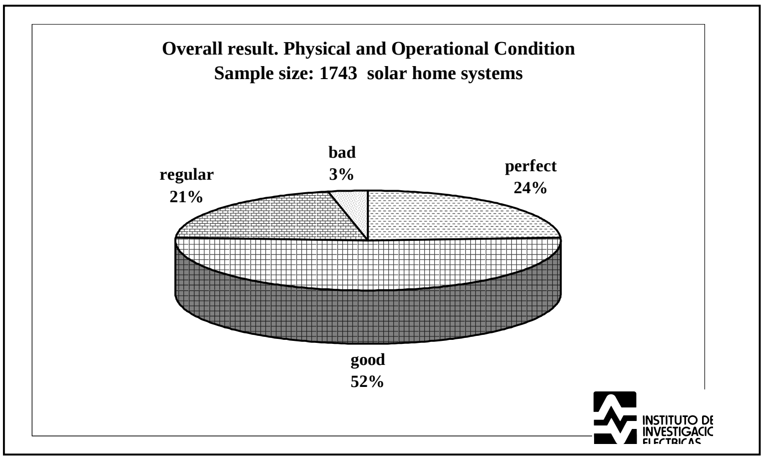

Figure 4.2: The physical and operational condition of 1,743 solar home systems in Mexico (preliminary results) [Huacuz et al, 2000].

[2] This is the complete text of the note from Huacuz et al. We are grateful for his kind permission to publish his note in this report.

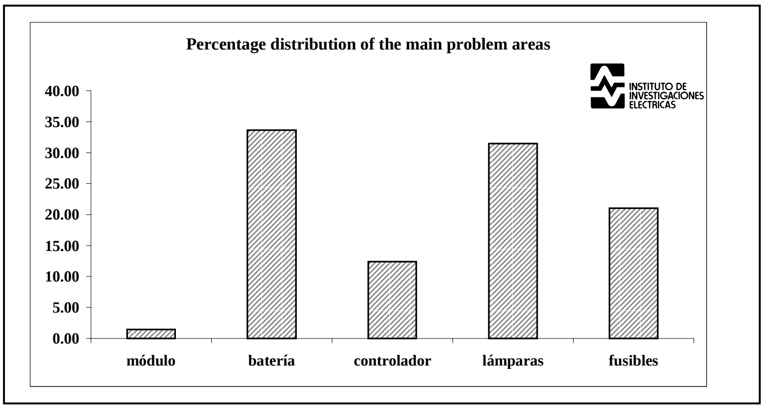

Figure 4.3: The main problem areas for 1,743 solar home systems in Mexico (preliminary results) [Huacuz et al, 2000].

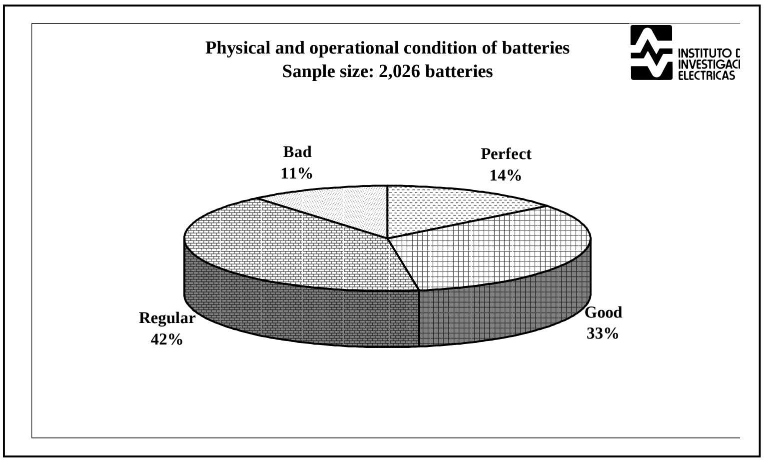

Figure 4.4: The physical and operational condition of a sample of 2,026 batteries from 1,743 solar home systems in Mexico (preliminary results) [Huacuz et al, 2000].

Philippines

In the Gregorio del Pillar PV project in the Philippines, monthly checks on the condition of the systems are performed. They show very few instances of total systems trouble. The most unreliable component turned out to be the light, as can be seen in the following table.

Table 4.1: Solar home system component failures in Gregorio del Pillar, Philippines

Component	Number installed	Failures Year 1	Year 2	Year 3	Year 4	Total Failure	
						#	%
PV	129	0	0	0	N/A	0	0
BCU	120	0	0	0	N/A	0	0
Battery	125	2	3	12	33	50	40
8 W FL	75	2	1	0	N/A	3	4
9 W PL	150	48	18	0	N/A	66	44
11 W PL	100	1	6	0	N/A	7	7
Total	1374	53	28	12	N/A	93	7

Source: [RSVP, 1997]

Tunisia
In a survey in Tunisia, of inspected systems 38% fully operational after 7 years, 37 % with restrictions, 25% defunct [AME, 1999]

Based on the cases from the countries discussed above, it can be concluded that in general, the lights and batteries are the components that cause most of the problems in solar home systems. In the remaining part of this section 4.2, we focus more in detail on the different components.

Only from a few projects and countries, information could be obtained about percentages of systems that were found to be working or not working. These outcomes are summarised in table 4.2. Please note that the figures have to be interpreted carefully, since different methodologies have been used to assess the quality of the system. Also the lifetime of the systems in the field differ widely. For example, in the case of the Rama Krishna Mission in India, the systems were installed less than a year ago. Their excellent performance is therefore not a surprise.

Table 4.2: Overview of status of solar home systems (numbers are percentages of investigated systems)

<table>
<tr><th>Country</th><th>Good</th><th>Partly inoperational</th><th>Inoperational</th><th>Source</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Kenya</td><td>60</td><td>30</td><td>10</td><td>[Acker, 1996]</td></tr>
<tr><td>Kenya</td><td>77</td><td>2</td><td>21</td><td>[Hankins, 2000]</td></tr>
<tr><td>Tunisia</td><td>38</td><td>37</td><td>25</td><td>[AME, 1999]</td></tr>
<tr><td>India, RKM</td><td colspan="2">98</td><td>2</td><td>[TERI, 2000]</td></tr>
<tr><td>India, Urjagram’93</td><td colspan="2">51</td><td>49</td><td>[Annex 4]</td></tr>
<tr><td>India, Leh</td><td>71</td><td>27</td><td>2</td><td>[Annex 4]</td></tr>
<tr><td>India, Kargil</td><td colspan="2">96</td><td>4</td><td>[Annex 4]</td></tr>
<tr><td>Guatamala, Zacapa</td><td colspan="2">55</td><td>45</td><td>[Alavarez, 1999]</td></tr>
<tr><td>Mexico</td><td>76</td><td>21</td><td>3</td><td>[Huacuz et al, 2000]</td></tr>
<tr><td>Kiribati</td><td colspan="2"><10</td><td>>90</td><td>[Annex 5]</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>55</td><td>20</td><td>25</td><td></td></tr>
</table>

From the table it can be concluded, that in the dissemination activities for which information could be obtained, about a quarter of the systems is not working anymore, and an additional one-fifth of the systems is only partly operational.

4.2.1 Module quality

Solar photovoltaic modules are the least problematic component of solar PV systems. Some degradation in output of crystalline modules is reported of about 1% per year. Output degradation was a serious problem with amorphous silicon modules in the past. However, recent field tests show that quality has improved. In a project in **Kenya**, I-V curve measurements were conducted in 145 homes and 14 test field installations of five different amorphous silicon modules of three brand types that have been in the field between a few months and 10 years. When measured power of the amorphous silicon modules was compared to rated power, one module produced 83% of the 12 Wp rating, two types of one brand produced 88% and 89%, and two other modules of one brand produced 61% and 55% of rated power[3]. This compares to a sample of 17 crystalline modules where measured power was about 87% of rated power. It can be concluded that the good brands of amorphous silicon modules have a similar output. [Duke et al., 2000]

[3] I-V curves were normalised to standard test conditions of 1000 W/m^2 and 25 ^0C.

In **Brazil** a larger rate of degradation of PV-modules have been reported. The average value of the normalised efficiency decreased with 8% from 12.7% after one year to 11.3% after three years of operation. The open circuit voltage remains the same, while the short circuit current is reduced by 8%. [Barbosa and Fraidenraich, 1997]

4.2.2 Battery quality

It is not always realised that batteries are usually the most expensive part of a solar home system over the lifetime of the system. Lifetimes of batteries vary considerably from project to project, from less than one year to more than four years. Usually, ordinary car batteries are applied which typically live between one and two years only in a solar home system.

Initially, 100 Ah batteries were installed in the solar home systems in Sukatani in **Indonesia**. These systems have two 40 Wp modules and a typical load of only 43 Watt, consisting of lights (22 W), a black and white TV (14 W) and a radio of 7W. Based on the monitoring outcomes, BPPT advised to use 70 Ah batteries. Lifetime of the original batch of 100 Ah batteries was very long: about 50 months. Average lifetime of the 70 Ah was only 7 months less (-15%). However, a 70 Ah battery costs about 30% less. Furthermore, it was noted that differences between car batteries and solar batteries were only marginal. Locally produced automotive batteries with a capacity of 100 Ah last only 3 months less than the initially installed batteries that were designed for solar applications. [Reinders, 1999]

The locally produced batteries used in the Banpres project in Indonesia, were often far from fulfilling the characteristics specified by the manufacturer. Most batteries reach only 80% of the rated capacity, even when new. [Fraunhofer ISE, 1-7-1998] Users mentioned that replacement batteries did not last as long as the original ones; their explanation is that they could not buy the same quality as initially. This is mainly because they did not know where to buy them. [Fitriana et al. 1998]

Battery quality control is the major problem in the K-REP project in **Kenya**. Almost all batteries were from one manufacturer. All were “Solar Batteries” (modified SLI-type flooded lead acid) of 75 Ah or 100 Ah. Most were over one year old when failed. Of all failed batteries, only 2 did not have charge regulators (in one case the regulator had been disconnected by the owner). It is likely that batteries failed because of (1) quality control problems in the factory in Kenya or (2) long periods on the shelf under self-discharge before delivery. [Hankins, 2000]

In the **Pacific**, batteries in systems that are user owned and user maintained showed early battery replacements for two reasons: (1) systems are usually undersized in an attempt to get initial costs down; and (2) poorly trained users or institutional "handymen" usually replaced batteries without determining why the battery failed. Excessive shading, incorrect controller settings, improper panel orientation, excessive loads, wires too long or too small, appliance problems and poor connections can all cause real or apparent early battery failure. While replacing the battery appears to repair the system, in fact the new battery may also be doomed to a short life since the other problems persist. [Wade, 2000]

In 1991, Enersol conducted a battery performance field study of 18 PV systems based on actual battery life data for Sandia National Laboratories. The study found that, when used with PV systems, 60 Ah "Meteoro" brand batteries typically last about 18 months. The study shows that despite such low cycle lives, local batteries are competitive - on the basis of energy delivered - with imported batteries. [Hankins, 1993]

One of the most detailed reported studies about battery performance in solar home systems describes the performance of 555 batteries in seven different states in **Mexico**. These systems include a 48 Wp or 51 Wp module, a 20 A on/off shunt-type battery charge regulator, a lead-acid battery of 50-104 Ah rated capacity, a lighting load of about 60 Watt, and occasionally an additional load of a radio or television. Batteries receive a grading based on a number of rating factors. A fair grading results from gassing electrolyte, wrong or missing caps, loose contacts, or unauthorised connections. A bad rating is the consequence of battery voltage below 11 Volt, specific gravity below 1.2, a broken case, shorted out cells, corroded, broken or missing terminals or connections or a system that is out of order. With this rating system, it was found that 58% of batteries was in a perfect condition, 38% good and 4% in a fair condition. Note that the batteries in this survey are relatively new, with an average lifetime of less than a year, and 55% less than six months. Three of the most common anomalies found were low electrolyte density (47%), high electrolyte level (13%), and low voltage (11% of the anomalies). The higher the nominal battery capacity, the better the rating. They therefore define a rule-of-thumb that the battery capacity should be at least seven-and-a-half times the daily load in Ah. [Huacuz et al, 1995]

4.2.3 Charge regulator

Charge controllers make up only a small fraction (about 5%) of the cost of a solar home system. However, its proper operation is expected to guarantee a sufficiently high lifetime of the battery, although this could not be supported by field data. Inadequate user training often leads to bypassing the charge controller. Some advanced controllers have special features to enhance the lifetime of the battery (boost charging and pulsed charging) or improve charging efficiency (pulse width modulation). No field test results could be obtained that support these claims.

In almost all the SHS of the Banpres project in **Indonesia**, the charge controllers have been bypassed. They did not work very well from the beginning, may had to be replaced, and even 5 years after the programme, those still present, are not working well. When it became clear that the controllers were restricting the lighting duration, the local technicians did not see any alternative than to bypass them. [Fitriani et al, 1998]

‘Laboratory tests of nine charge regulators used in the Banpres project showed clearly that many manufacturers receive their knowledge about the optimal operation of lead-acid batteries from the literature instead of real components and operating conditions. The right approach would be to do random charge and discharge tests with the concerned batteries, to take the characteristic parameters and to adapt the thresholds and the operation of the charge controller to the respective battery.’ [Fitriani et al., 1998]

The most common defect of charge regulators in the Rural Photovoltaic Electrification programme in the **Philippines** was defect of the switching transistor, often a MOSFET. This type of transistor is locally available, but very expensive, taking about 40% of the cost of the controller. [Navarro, 2000]

Semi-deep discharge batteries were installed in the Buena Ventura Solar Electrification project. They were found to last for 3-4 years. Controllers have LEDs to let the family know the state of charge of the battery. There is not an automatic disconnect on the controllers because it was found that with an automatic disconnect, the users do not understand why their systems have stopped working (they think it is broken) and they "fix" it by bypassing the controller. On the other hand, by telling people how long they can use their appliances, they realise their system will go down if they use too much electricity and they prevent the problems before they happen. [NRECA, 1996]

Users do not know how to bypass the low voltage disconnect feature of the controller unless technicians teach them so. With proper education, users will learn to manage their consumption well instead of tinkering with the system. [Navarro, 2000]

In a survey of 91 households in **Kenya**, the systems without charge regulator were all small systems (12-20 Wp) and were mainly for one light and a B&W TV only. The systems were well-sized for intended loads. [Hankins, 2000]

System status lights and other forms of indicators are very helpful for the users at the start. As they use the system along, the users develop a feel of what the system can deliver depending on the weather. On the second year of operation, users hardly look at the indicators unless the battery begins to prematurely deteriorate. [Navarro, 2000]

Sufficient evidence was found in **Mexico** to conclude that malfunctioning battery charge regulators and regulators with improperly set disconnect/reconnect voltage values, are often the cause for failed batteries. Most battery charge regulators in the installations surveyed have an override switch which allows the user to manually reconnect the load after low voltage disconnect. About 21% of the battery charge regulators were found with this switch in the manual position. The override switch was included by design engineers in earlier models of charge regulators. After finding that this switch was an invitation to system abuse it was banned in later projects. [Huacuz et al, 1995]

New and sophisticated types of controllers are often claimed to improve the performance of systems and the lifetime of batteries. However, present experience is inconclusive. Good results are often obtained with well-built, but rather simple controllers [Lorenzo, 1997]

4.2.4 Lights

Lighting is the most common application of solar home systems. In India, the common name domestic lighting system is also used when a television set is powered. Lighting with solar PV provides cash savings on fuels such as kerosene. In those cases where solar home systems are used for (indirect) productive applications, it usually involves lighting. Lights are often provided as an integral part of a solar home system.

The quality of different lights can vary considerably between more or less comparable lamp types. As is illustrated in table 4.1, one lamp showed a ten times higher failure rate than a more or less similar lamp type. A problem in maintaining quality of lighting is the relatively small market for 12 Volt lamps.

If the lamp breaks down, the user will always treat the whole system to be damaged. The lighting fixtures used in the system should be as reliable as the rest of the system. The most expensive lights are not necessarily the most durable, and the cheapest light does not have to be the least reliable one. [Navarro, 2000] Some lights in the **Philippines** which were earlier found to be the best might not have the same workmanship in later batches. [RSVP, 2000]

Three fluorescent tubes of 18 Watt have become the standard in **Tunisia**. PV-lamps offered on the Tunisian market do not meet the quality requirements of AME. This is linked to the fact that imported components of satisfactory performance are not available on the commercial market, as they are subject to high taxes and import duties. [AME, 1999]

In a number of cases people mentioned an interest in a light for orientation purposes which can be lit the whole night. For this purpose 6 to 18 Watt fluorescent lights produce much higher lighting levels than actually required. 1 to 2 Watt lights can be sufficient for most cases. Since the efficiency of 1 Watt fluorescent lights are comparable to incandescent lamps, the latter is a much cheaper solution and is easier to implement.

Incandescent bulbs are often preferred over fluorescent tubes, because they are cheap and simple to use. Bulbs can still glow even if the battery is almost flat. Due to their inefficiency, the use of high wattage bulbs should be discouraged, but there is room for bulbs with a power below 3 watt for orientation purposes. [Navarro, 2000]

For fluorescent lamps, colour tone is important. Europeans often prefer warm white light, while Asians generally like bright white daylight. A mismatch happens when lights were procured from Europe and used in Asia, without prior colour tone preference specified. [Navarro, 2000]

In a project in the Northeast region of **Brazil**, a large fraction of the light switches were not working properly. Most of the lamps have no switches, and are turned on by simple connection of the wire ends. Note that the switch is a simple component from an electrical point of view and one of the cheapest parts of the system. However, its malfunctioning can be the reason for the whole system failure. [Barbosa and Fraidenraich, 1997]

Tim Ball of Applied Power Corporation, U.S.A, a company that has supplied over 3,000 solar home lighting systems in developing countries mentioned that he is "not aware of any report that clearly defines how factors such as switching frequency, voltage, waveform, crest factor, etc., impacts the efficiency and lifetime of fluorescent lamps. Such a study would be beneficial to APC and other PV system integrators . . . if you consider that over 30,000 PV lighting systems will be installed in the next couple of years each with an average of 3 lamps, it seems obvious that there is a significant need and justification for such a study." [Inversin, 1996]

It was found that the number of lights required per system differ widely in different projects. It is clear that household demands are not equal. Programmes should allow for these large differences between demands of users.

4.2.5 Technical problems with solar lanterns

In a demonstration project in Masaai land in **Tanzania**, three commercially available solar lantern types were sold for prices between US$ 167 and US$ 200 at the end of 1995. Module power was 5 or 10 Wp. One of the lanterns showed problems with the cable junction to the module. Furthermore it caused radio-interference at 1.5 meter distance. Less than half of the modules had been permanently mounted on customer roofs. The rest were left on the roof or on the ground. Some users changed the orientation of the module two or three times a day. [Hankins and Thagichu, 1996]

In a test marketing study funded by the World Bank, 7 solar lantern brands were distributed in **Kenya**. Of each type between 30 and 60 pieces were sold for the projected long-term prices ranging from US$ 40 to US$ 100. Findings:

- The main technical problem is that sealed lead-acid batteries are used which are not suited for lantern use without specially adjusted low voltage disconnect. End-users commonly use their battery without recharging until the battery is exhausted.
- There is room for improvement of the luminaire design. Several of the fluorescent lamps had unacceptably low light output. Light colour matters, and users are not willing to accept monochromatic LED cluster lamps. Lamp diffusers and reflectors can be improved.
- Only two of the seven lanterns had the possibility to operate a radio or a television set. This possibility was highly appreciated by the users.
- Module mounting has not been addressed by lantern manufacturers. Haphazard placement of the module in the sun can result in significantly lower energy generation. Only one of the lanterns included mounting brackets with its kit.
- All modules produced substantially less than rated power during normal operating conditions at noon, where cell temperatures were higher than 45 ^{0}C. Average measured power of the four crystalline modules was 66% of rated output, compared to 77% for the amorphous modules. [Hankins, 1997]

After 12 months, a survey was conducted to study the failure rates in this World Bank project. Information about 47 lanterns were obtained through dealers and interviews of owners. Of four different lantern types, the reported failure rates were between 30 and 50%, with an average of 40%. However, one expect some underreporting of failures due to the fact that people living in remote areas do not return their failed lanterns. It is therefore estimate that the actual failure rate is 50% or higher. [Polak, 1997]

4.3 Quality assurance of SHS components

Experiences with technical problems with solar home system components differ widely. Some systems do not function from the start, while others work for 10 years without major problems. Sometimes good quality components fail more rapidly than foreseen, due to wrong use. But usually the quality level is low because of inadequate designs or lack of quality control during production.

In **Tunisia** it was noted that it was very difficult to maintain quality levels over time. Since the producers constantly change their products and often sell products from other manufacturers under their label, the equipment offered by the same supplier may vary considerably from one call for tenders to the next. Even the results of tests of components are often out of date as soon as they are published, as the tested model has already been replaced by the producer or supplier. [AME, 1999]

Practical problems arose during evaluation of calls for tenders by AME in Tunisia. Sometimes, the quality of twenty or more different models of ballast or charge regulator had to be judged in the limited period of about three to four weeks. Only some basic tests could be performed. Nevertheless, the basic, quick tests already proved that a considerable number of the components offered did not correspond to the specifications of the tender documents, or that the suppliers had interpreted these specifications in an unintended way. Some examples of the need for careful formulation and implementation of requirements are the following cases:

- A supplier claimed that his ballast, in spite of causing interference that made it impossible to listen to the radio when the lamp was switched on, should nevertheless be classified as protected against interference, as the normal radio frequencies in his home country were not affected.
- A manufacturer declared that his charge regulator was protected against inversion of the polarity. In reality, the regulator itself would not be damaged in such a case, but the loads (radio, lamps, TV) were not protected!
- A ballast, faulty after only a few minutes of operation without the tube, due to overheating, was characterised by a supplier as protected against idle operation, as a minimum delay of operation without tube or a maximum temperature were not indicated in the tender documents.
- A producer refused to change his charge regulator, which had shown some problems during the warranty period, with the argument that AME had certified the equipment. In reality, the simple tests executed by the engineers and technicians of the agency could not reveal the hidden problems only found afterwards when the SHS were installed in the households. An official certificate had never been granted. [AME, 1999]

Tender procedures can also have a negative impact on sustainable quality levels. In Tunisia it was observed that because of strong competition, the favourable offers have generally been calculated with a low margin for profit and unforeseen difficulties. In case of quality problems with a component, which might first be seen after the installation of hundreds of systems, the financial losses due to the warranty become enormous. This might easily threaten a small or medium-sized enterprise with bankruptcy. In order to avoid this, some suppliers try hard to refuse all claims for warranty and deny responsibility. [AME, 1999]

In **Mexico**, authorities have opted for an informal set of quality indications, which are used by the government or municipal agents to test the incoming tenders. The advantage of dealing with quality indications instead of obligatory quality standards is that a) there is no need for time consuming legal procedures to have the standards adopted formally, and b) there is ample scope for choice; users (municipalities) can choose to accept lower quality in exchange for lower system costs, extension of after-sales services, etc. The choice for quality indications instead of formal minimum quality standards implies the need for better systems of information, in order to assure that the buyer of the system is aware of the choices that are being made.

4.4 Local production versus import

Lower costs is often one of the incentives to promote local production. Price differences for those parts with an established local market can be considerable. For example, Rahim Afrooz **Bangladesh** Limited quotes US$ 34 for an imported mounting structure for the module, compared to US$ 11 for a locally made one. Imported luminaires for fluorescent tubes cost US$31 compared to US$ 11 for a local product. However, due to the need to import the PV-modules, an imported 40 Watt solar home system only costs about 25% more than a system with locally produced BOS-components [RahimAfrooz, 2000].

Both local automotive and imported solar batteries were used during the Rural Photovoltaic Electrification programme in the **Philippines**. Even the best, flooded-type solar batteries can be outperformed by a local automotive battery if maintenance is not done. The cost of imported batteries can be twice that of a local automotive battery while the performance under tropical circumstances is almost the same. It is often practical to use good quality local automotive batteries than to use imported solar batteries. [Navarro, 2000]

In the Philippines, difficulties were experienced with the electronic components such as the battery charge regulator and the electronic ballast for fluorescent lamps. After having experienced heavy problems with locally manufactured low-cost ballasts and charge regulators, a Philippine company was assisted in producing new designed components, but the results were discouraging due to the low performance of the new products. [Muller-Klinghammer et al 1998]

In **Indonesia**, local production takes place of all solar home system components except for the solar cells. The largest local producer succeeded in overcoming the financial crises in 1998 by shifting its major focus to export. The company’s success story is an example that local production can reduce cost of system components while still maintaining sufficiently high quality.

4.5 Conclusions and recommendations

There are still many remaining technical problems and this aspect is not given sufficient attention. Continuous product development is necessary to incorporate the technical lessons learned.

Often tendencies exist to increase the local content of the solar home systems. To safeguard quality, local assembling of balance of system components can be considered in countries with high import tariffs and a sufficiently large domestic market.

Improved designs for charge regulators are required to extent the lifetime of batteries and thereby reduce the lifetime costs. Design changes need to be based on field experiences and feed back from users in different countries. It is recommended to obtain this information via monitoring activities using data loggers and surveys.

Good amorphous silicon modules are presently on the market, which can perform in practice as well as their crystalline counterparts.

Early battery failure is mostly a symptom of other problems. Though most photovoltaic system failures are evidenced by a failed battery and its replacement apparently fixes the system, if an early battery failure occurs a complete system check should be made to insure that other problems do not exist. Almost every problem with any part of a photovoltaic system can result in shortened battery life. This is the main reason that regular preventive maintenance is important. [Wade, 2000]

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5. EVALUATION OF END USER'S EXPERIENCES

5.1 Introduction

In this chapter we will look into the user aspects of PV implementation, both from the perspective of the users themselves (what influences the users' satisfaction with a PV system and what are the impacts of PV for the users) and from the perspective of PV dissemination (what are the impacts of the users on the functioning of the PV systems and on dissemination itself).

This chapter is based mainly on the results of a number of socio-economic studies in the field of PV. The database set up during the project containing all project data found in project documents has been used to check the findings and to provide examples of experiences with the studied issues. The database was not used for statistical analysis for the evaluation of end user experience for several reasons. Firstly, very little information on user aspects of PV dissemination is given in most documents. Secondly, most remarks found on this subject in the researched literature are based on presumptions rather than on findings. Finally, the issues on user experience are mostly so complex, that the context of the findings is essential for a reliable interpretation.

This leads to a case-based analysis. From the detailed case studies, backed up by examples from the database, the most important factors of influence and some remarkable findings on user experience can be identified. In this chapter, we do not aim to make globally valid remarks that could be used as a blueprint for PV projects.

5.2 Social- economic background of PV users

Identifying characteristics
Who are the users of PV systems in low-income countries? What are their common and differentiating characteristics? The most obvious questions for getting an idea of the users are: Where do they live?; What is their income (relative to the PV system and relative to other people in their surroundings)? and: How do they earn a living? Less obvious characteristics surfaced during the research as important differentiating factors: What is the experience of users with batteries?, and: Who uses the system within the household? In answering these questions, it appeared that it is necessary to make a distinction between users of PV systems who have acquired systems in the commercial market and those who have acquired systems through partially or totally subsidised projects or programmes.

Geographical location
In government or development aid supported programmes, which nearly all have a development objective, the great majority of PV users live in rural areas where there is no access to the electricity grid. Areas are selected using criteria such as poverty, inaccessibility and the lack of perspective to acquire access to grid electricity on the short term. Most live more than 10 km from the grid.

The geographical location for commercial distribution shows a large contrast. Although the literature does not specify this, it seems that most PV users of commercially obtained systems can be found within a limited radius of the supplier of PV systems. These users live in nearby villages, and even in (peri-)urban areas. Here grid electricity may be (perceived to be) just as unavailable as in rural areas. If grid electricity is available, PV may still be preferred if the grid electricity is unreliable or has load shedding (i.e. Ghana). In India, for example, urban agglomerations are an important commercial market for PV systems.

Income

The largest user group of PV systems consists of relatively well-off inhabitants who acquire the system for their own use. They acquire PV systems on the commercial market. We will look into this user group first.

The characteristics we would like to identify here are the costs of PV systems compared to income, and the income of PV users compared to that of non-PV users. Regrettably, the literature does not provide sufficient (reliable) data to make a reliable statistical analysis of this question. The few case studies encountered with good information on this subject, show large variations in incomes of PV users.

When comparing system price (cost for the end-user) to income, large variations appear. While in Namibia [Wamukonya, 1999] a 50 Wp PV system amounted to slightly more than one tenth of the annual income of the average user, in Nepal [AEPC/DANIDA, 1999] SHS commonly cost between half and one quarter of an annual income. Within the small area of Swaziland [Lasschuit, 1999a], the whole range of costs relative to income occurs. Although the costs of PV systems was generally around one tenth of the annual income, for rural teachers, who are one of the common groups of users, costs amounted to 4-6 months' salary.

According to our expectations, the incomes of users acquiring SHS on the commercial market (even when the systems are subsidised) are higher than those of non-PV users. The difference is sometimes very small, though. In Nepal [AEPC/DANIDA, 1999], the average income of SHS users compared to that of non-SHS users was 1.2 times to 2.5 times as high. In Namibia, the income of PV systems users was a factor three higher than that of the average rural population [Wamukonya, 1999]. A remarkable result of the study in Nepal is that the demand for SHS does not increase with income level. Although one would expect the percentage of SHS users to increase along the income scale, the group with incomes between Rs 40 000 and Rs 80 000 has the highest percentage of SHS users (a SHS cost Rs 18 000). In Namibia and Swaziland however, research results give the perception that SHS users generally belong to the highest income groups in rural areas.

A different user group consists of people who have acquired their PV systems through a well-off relative living in town or abroad. In Morocco, a large number of PV systems have been imported by Moroccans who have worked in Europe (although no figures are to be found in literature, a best estimate would point at several thousand imported SHS per year). Research in Swaziland [Lasschuit, 1999a] shows that 38% of interviewed buyers of PV systems were not residing at the house where the system was installed. These buyers are often heads of households working in towns while their family stays in the rural area.

The user group targeted by government or donor programmes with socio-economic objectives, differs greatly from this first group. These users of PV systems are relatively poor and are expected to lack the financial means to acquire systems through commercial market channels.

The information on the user group of PV lanterns is scarce. Lanterns are used by well-off groups in towns as easy transportable light, by tourists or for recreational purposes, and by low-income user groups (especially in subsidised government programmes in India).

Employment

Common characteristics of users of commercially distributed PV systems are: a higher and more regular income and better access to information from towns than the average inhabitant of rural areas. Owners of stalls or small shops, people working in tourism and trade, expatriates, teachers, police officers, soldiers and nurses are highly represented. The study in Nepal [AEPC/DANIDA, 1999] shows that, when totalling all income of SHS users, non-farm income (through trade, salaries, pensions, house rent) is higher than farm-income. One important factor defining this user group is the requirement for a regular income to qualify for a loan in most hire/purchase facilities.

As can be expected through the link to rural or isolated locations of PV systems disseminated through rural development programmes, a common characteristic of the second group of PV users is employment in the agricultural sector.

Use of batteries
In the market for commercial dissemination of PV systems, many owners were already using batteries for television before they had a PV system. Research in Swaziland [Lasschuit, 1999a] showed that 31% of interviewed SHS users built their SHS starting from a battery and television. This is much less the case for projects or programmes with socio-economic objectives. This is an important finding, as the understanding of electricity and the use of batteries is also commonly better than that of user groups who have had no experience with batteries.

Gender
Although the awareness of gender issues has been a topic in social and development issues for a long time, in the dissemination of PV systems it is still commonly forgotten that it is relevant to look further than the borders of a household. Within the household, the differences in the tasks and responsibilities of the household members also applies for the use of PV. In general, women are the main users of the system, as women usually spend more time in the home than men and children.

No mention is made of specific objectives for the development of women, or women as main target group in the literature used for this project, showing that there is still hardly any attention for the role division within a household. In the social studies evaluating programmes, gender does commonly play a role.

5.3 User experiences and role of the users of PV systems

5.3.1 User versus technology focus

Now we have formed a picture of the users of PV systems, we can discuss the 'user experience'. We will look at the experiences of the users with PV systems- how satisfied are they? We will also view the users from the perspective of dissemination of PV systems- the experiences *with* users- as the users themselves play a decisive role in the success of dissemination and use of PV. This paragraph touches upon many of the subjects mentioned in previous chapters, as can be expected. The actual impacts of PV systems on the lives of the users are discussed separately in the following paragraph.

Firstly the experiences of the users themselves. The first factors the users will provide on this subject are the provided energy service and the availability and quality of maintenance and service. The satisfaction with provided energy depends largely on the demand of course, so this is discussed first. Although the user may not experience it as such, the user understanding of the system is also essential for both the handling and the satisfaction with the system. The willingness to pay is often a measure for the user satisfaction.

Secondly the experiences from the point of view of PV dissemination. From the many experiences in the field, it becomes obvious that the focus of PV dissemination is on technology. The role of the user is not the main issue, although designing high quality products that can meet the demands for energy service, and financing issues are generally taken into account. Important aspects in which the role of the user is relevant for the success of the technology are discussed in this chapter, including the user awareness of the general market before acquiring a PV system, understanding of the system and the ability and willingness to pay. Of course the influence of the user is also discussed in the paragraphs on technical functioning and maintenance.

Although the aspects mentioned above overlap and influence one another considerably, we have tried to box the issues into separate paragraphs. The reader will be showered with linkages and references, so that the issues will be clarified in their full complexity.

5.3.2 Energy demand

Appliances

Before we enter into the discussion on user satisfaction, we will try to further define the actual energy demand. The first aspect of the user demand is the demand for use of certain appliances. The second aspect is when and how frequently use of these appliances are required.

In general, the main use of SHS is for lighting. Better quality and less dangerous light compared to conventional lighting options such as candle and paraffin lamps, is the most important reason for people to buy a SHS [Wamukonya, 1999] [Green, 1999] [Alvarez, 1999]. However, lights are not always attached to the PV system. Research results in Swaziland [Lasschuit, 1999a] show that 18% of SHS users did not use the system for lighting. Television is given a higher priority than lighting in a significant part of the market for SHS.

Firstly, we will have a more detailed look at lighting. The lights applied for SHS are usually 6-20W fluorescent tubes, providing a significantly brighter light than possible with traditional lighting. Given the limited output of PV systems, there is clearly a demand for orientation light with a low wattage. These are used for toilets, in hallways, and when bright light is not necessary. Several sources mention that the small 3W or smaller lamps are appreciated for orientation lighting. In Indonesia, it is quite common to add a number of small lights for orientation to the SHS. Zilles [Zilles, 1997] performed a study into the use of small 2W incandescent lamps in Brazil, concluding:
'.. the use of incandescent light is preferred to the use of the fluorescent ones during most social gathering periods of the day' .

The number of lights installed with a 50 Wp system is usually two or three. The demand for a certain number of lights, however, depends strongly on cultural factors related to building and living style. The demand for more lighting fixtures than standard supplied is also prevalent in rural Senegal, where it is common that a man has three wives, who each have their own dwelling [Dahouenon, 1994]. In commercial projects, where the user defines the system, several small systems are commonly preferred above one central system in these cases. In some cultures, the high quality (higher luminosity) light is always installed in a room where guests are received. In this case, the rooms in which the daily life takes place do not all have a PV lighting fixture. Here lower quality lighting such as kerosene lamps is used, unless more lighting fixtures can be acquired.

It has been found that it is not common for users in government programmes to increase the number of lighting fixtures, even if they are not satisfied with the number of lights. Reasons for this may be lack of understanding, but it is thought that the pressure exerted by projects to limit the number of lights is the most influential factor.

In project defined systems, not only the number of lights, but their location also often does not meet the user demand. In Tunisia, for example, there was a large demand for lights on the porch, where families sit outside in the evening. The project had placed all lights inside the house, and the fixtures were not suitable for outdoor placement [Hammamami, 1999].

After lighting, the most common applications of SHS are television and radio. Black and white televisions are rapidly being replaced by colour televisions since these are becoming available on the market in 12 Volt versions. There are examples from the field where television has a higher priority than lighting. In Brazil, users are highly satisfied when they can use a television, and there is hardly a demand for systems that could provide more services.

There does not seem to be a large wish for other applications besides light and television and radio, although refrigeration is mentioned especially with high income PV users [Wamukonya, 1999]. Occasionally, SHS are used for sewing machines and videos.

For radios, the added value of SHS is often a large disappointment for the SHS user. Dry-cell batteries still have to be bought at considerable cost. The main reason to continue using dry batteries for radio is that the possibility to use a radio at different locations, also outside the house, is valued highly by many users. Also, in Namibia, the voltage of the SHS does not match that of the most common radios. [Wamukonya, 1999].

The priority of light or television /radio differs per country and region. Studies show that while in some areas it is common usage that lights are switched off when the television is switched on (Tunisia, South Africa) [Hammamami, 1999], or the system is only used for television as in Brazil, in other areas the lights are most important (Ghana).

Usage patterns
The daily and seasonal usage patterns depend strongly on the geographical position, as can be expected. Generally, lights are used to extend the day in the evening. Notice is given of getting up earlier in the morning [AEPC/DANIDA, 1999]. Adaptation to seasons is necessary in regions at a distance to the equator. In Tunisia, the necessary adaptations are significant.
Detailed monitoring in Tunisia showed that the users adjusted their energy consumption to the supply, although not always sufficiently. Typical behaviour was that more television was watched in summer than in winter, with a significant peak during children' s summer holidays. In winter, to save energy, the lights were switched off when the television was on.
These patterns can be generalised to different countries, although the energy demand certainly does depend on the use, which can be a cultural factor.

5.3.3 Energy service provided

System size
The demand for a certain system size seems to have a lower and an upper limit, depending on the required use. The requirements vary widely, however, as we have seen in the discussion above. One general conclusion from research results, however, is that users with larger systems are generally more satisfied with their system. Advantages of larger systems are that more appliances can be used for longer periods of time, but also that the systems are more reliable in the users' experience. The reason for the better reliability of larger systems is that deep discharging occurs less frequently in larger systems, as shown in the large GEF funded project in Zimbabwe. [APTECH, 1995]. A study in Bangladesh comparing the user satisfaction of differently sized systems had the following results:

- Users of a 46 Wp systems -34% rated their system as good, 37% satisfactory;
- Users of 2 * 46 Wp systems- 67% rated their system as good, 26% satisfactory.

Experience in Tunisia follows the same line: user requirements of a television and 3 lights influenced the government programme to increase system size provided to more than 100 Wp. [Hammamami, 1999]. This one programme is an exception though- in most government programmes the role of the user in the choice of size of PV systems is small. In commercial markets, the evidence shows that there is a demand for a range of sizes to meet the different user demands.

Technical functioning
As discussed previously in chapter 4, the functioning of PV systems is rarely perfect. It is to be expected that the satisfaction of the users is closely linked to the technical functioning of the system. Literature shows that it makes no difference to the user what the cause is of the

malfunctioning- broken lights are just as problematic as malfunctioning panels, if spares are not available or affordable.

However, it has been found that users do accept systems of lower quality and performance in an open market where the relation between price and quality is clear. In Senegal [Sarr, 1998], both user groups of systems without controllers and with higher quality but higher price were satisfied with their PV systems. In Kenya, where the market for PV is fully developed and offers a range of systems sizes and qualities, smaller systems using low quality components such as car batteries are very popular.

The role of the user on the technical functioning of the PV system is not negligible, although many design engineers would wish it were. As mentioned in the chapter on technical findings, damaging of the system is often caused by users discharging the batteries too deeply. Not only incorrect use, but meddling with the system (or adapting it to short-term benefit, from the point of view of the user) is a frequently occurring cause for decreased system functionality. Finally, the influence of the user on the technical functioning is decisive in maintenance and service, as discussed below.

Maintenance/service

Maintenance and service are far more important for the functioning of PV systems than most users and even project implementers seem to think. Miscalculations in requirements in time and money are common. Although maintenance is usually part of a project and often even of commercial sales arrangements, one of the frequently recurring complaints of PV system users is the absence of a (functioning) maintenance or service scheme or the costs of such a service.

In the cases that the user is expected to maintain and service the system, the quality depends strongly on several factors. The most important are: the understanding of the system and service and maintenance requirements, and: the costs and effort involved and the willingness and ability to invest. The user understanding and the ability and willingness to pay are discussed in a broader context in the following paragraphs.

The costs in *time and effort* spent on maintenance has been shown to depend for a large part on the dissemination scheme. Ownership of systems is an important influence on the willingness to invest (time and money) in maintenance. In many fee-for-service systems, users tend to take less care of their systems and spend less time on the small maintenance efforts that may be expected (such as replacing a light bulb or cleaning the panel). One must take into account however, that maintenance requirements may be underrated. For example, PV users do not necessarily have a ladder, making the cleaning of a system on the roof a large effort. In Swaziland [Lasschuit, 1999a] the panel had never been cleaned by 40%, once by 32% and regularly by 28% .

As mentioned in the paragraph on the user understanding of the system, damage to PV systems often occurs due to faulty maintenance and repair by the user. This is especially so if suitable spare parts are not easily available or too expensive. A number of projects have tried to prevent the users from damaging the system through faulty maintenance or tampering. For this purpose, sealed boxes are used in the Home Power programme in South-Africa. In the Belance Solar Electric Project (BELSOLAR) in the Philippines [Mendoza, 1996b] the risk of tampering is minimised through a user contract. In the user contract, the responsibilities of the end-user are spelled out. Any modification to the system without consent of the SJCU technician is considered to be tampering with the system. If there are any problems, the end-user may call upon a technician. In addition, the servicemen are instructed by the SJCU to inspect the systems from time to time. Until the systems are completely owned by the end-user, the end-user must consult a technician for any SHS modification (adding an extra light, connecting a radio or television, etc.)

5.3.4 User awareness and understanding of system

Awareness within the potential market

From studies in different regions (Dominican republic, Senegal, Lesotho, Brazil) it appears that awareness of PV systems spreads most effectively through word of mouth and seeing installed systems at schools, or neighbours. A quote from a case study in the Dominican Republic [Hankins, 1993] :

'marketing in DR has primarily been through word of mouth and demonstration. To facilitate demonstrations, Enersol occasionally lends lighting systems to dedicated technicians, who install them in their own villages and use them as exhibits to drum up sales. This marketing method has proven itself effective in introducing PV to new areas'

A detailed study into market awareness of PV has been performed in Lesotho [Green, 1999]. This study showed that there is little connection between awareness of the existence of PV systems and education, age, income, employment, or occupation. In 1993, 26% of the Lesotho population had heard of PV. In 1999 this had increased to 58% , mostly through seeing a system in the neighbourhood or at friends (74%) and for the remainder via the radio (15%). The impact of demonstration systems creating awareness of potential customers is high as 52% could also mention a dealer, but information on the need for maintenance does not automatically follow. 97% of the persons who had heard of PV systems did not know that maintenance is necessary. Results in Namibia are similar [Wamukonya, 1999]: 50% of the unelectrified population knowing what PV is, 64% of these being able to mention a solar technician.

Generally it can be observed that the witnessing of working PV systems is the most important factor for the opening of markets for SHS.

The awareness of the existence of PV is not the same as the awareness of the functioning, however. Even salespersons have been noted to refer to the importing agency when asked how a PV system works [ECN, 1999]. Evidence of the importance of dissemination of information on the functioning of PV systems is provided by a study in Zimbabwe [Cloin, 1998]. Of households in the identified target group, 60% knew what a PV system is. This information was spread mostly by seeing systems in the neighbourhood. However, 56% of the people who said they would like to buy a PV system thought they can cook with the system.

Following the low awareness of the functioning of PV, the awareness of product quality is also low. Although brand names of components are used for quality assurance, this is not sufficient for the users, especially if they have no idea of the importance of matching components within a system. Negative experiences with inferior systems have damaged the reputation of PV technology, for example in Southern Africa [ECN, 1999]. Although components may be of high quality the modules are often undersized compared to the rest of the system. Also markets have been damaged by fly-by-night traders who disappear before the customer can return to complain. Because hardly any customers understand the functioning of a PV system, trust in the sales network is especially important.

The user satisfaction depends on the understanding and expectations of the system. If people are accurately informed on the possibilities and limitation of a SHS, they know what to expect and can make an ‘informed judgement whether to buy a SHS or not. Such people are generally more satisfied with their system than those who were promised ‘heaven on earth’ .

Understanding how PV works

A general conclusion from the literature is that users do have a basic understanding of the use of PV systems, especially the sense of the link between energy consumption and insolation is generally present. A number of monitoring studies show that the users do adapt their energy use to the seasonal insolation patterns [Hammamami, 1999] [Schweizer, 1997], or that users save electricity to have a full battery for a party. However, many users have no idea of the concepts of electricity or batteries.

The understanding and knowledge of maintenance requirements depends very much on attention paid to user awareness and user instruction by a supplier or within a project. Many projects have special folders, booklets or posters especially for the users. These are commonly written in the local language, and are illustrated with pictures. The instructions include advice such as to clean the module and to fill up flooded batteries regularly with distilled water. This does not mean that the users understand the reasons behind these instructions, or will be motivated to carry them out. Especially when instructions are difficult to carry out (or impossible, such as in the absence of suitable replacement components), users may damage the system by taking measures as they deem appropriate. Examples include filling batteries with normal water or even acid when distilled water is not easily accessible.

That the background and experiences of users with electricity is an important influence is shown by the fact that experiences have been encountered with users who are too afraid of electricity to even change a light bulb [Lasschuit, 1999a].

Evidence shows that user training can be (unintentionally) gender biased. Studies in South Africa [APAS, 1999] and in Guatemala [Alvarez, 1999] show that training was provided for the men, while the women were the main users of the system. The South African study observes that the women are not familiar with the basics of the functioning of their SHS (e.g. the meaning of the LED lights on the controller). The gender bias is usually unintended- in the South African example, the training was aimed at the household member involved in the loan agreement.

That training often does not reach the intended effect is shown in the Guatemala Zacapa project [Alvarez, 1999], reporting the following experience:
'In each of its projects, The Fundacion Solar provided a group training on the use and maintenance of the systems before the equipment provider installed the systems in the community. During the installation, the company was then in charge of providing additional hands on training, and of monitoring the system at intervals of 30, 60, and 180 days. The majority of system users said they attended the training and had general knowledge of adequate maintenance procedures for their systems. In contrast, almost none of the users were able to correctly repair basic system failures. Instead of successfully solving problems, system users would often make false wiring connections, causing the regulator to fail, or they would simply disconnect the regulator.'

5.3.5 Ability and willingness to pay

It is very obvious that the ability to pay is one of the crucial limiting factors in the dissemination of SHS in low-income countries. The ability to pay and the willingness to pay are not the same thing, however. They will be discussed separately in this paragraph.

Firstly, the ability to pay. Research into the experiences in the field has made clear that the provision of credit and rental schemes enlarges the group of potential users significantly. In Swaziland [Lasschuit, 1999b], 40% of all SHS users bought the system on cash terms, and 50% on credit terms (the remainder of respondents either received the system as a present or did not answer the question)- even though the PV systems bought on credit were 90% more expensive. Here, the systems bought on credit also had a 25% higher average capacity- showing that the ability to pay limits the chosen system size.

Although credit schemes are necessary, ownership is generally preferred. In Namibia, despite benefits of a rental scheme, 93% of the surveyed households indicated a preference for a credit facility [ECN, 2000]. The underlying reason was that people like to own the asset they are paying for. Similar findings were found in a rural household survey in Swaziland [Lasschuit, 1999a] were 95% preferred a credit scheme to a rental scheme. Those who preferred a rental scheme were expected to get a grid connection in the short run and regarded the rental scheme as an ideal interim solution

The ability to pay *after* the initial decision to acquire a system is very important for successful dissemination through all financing schemes, for the user satisfaction and success of the market on the long term. Firstly, the user may not be able to fulfil downpayment or fees, secondly, the costs of maintenance and repair may be unsustainable.

In projects without a selection of ability to pay through a substantial deposit, default or non-payment is likely to occur unless measures are taken to ensure payment. For example through direct salary deduction [ECN, 1999]. The replacements of parts is often overlooked in the cost calculation of SHS, especially by users. Especially for batteries, the cost of replacement can become a crucial stumbling block [Hammamami, 1999]. An illustration from the Guatemalan study [Alvarez, 1999]:
' The difficulty with the savings is complicated and involves a series of cultural and economic factors, including:

- families' scarce financial resources, due to the subsistence style of living;
- the absence of custom of long-term savings in rural communities;
- the lack of a secure, efficient, and sustainable system for collecting the savings in order to deposit them in a secure account.

In the case of the five projects evaluated, the fact that they were 100% donation on the part of PLAN International constituted an important factor, since the system users were never required to make a financial commitment. In other communities studied in phase II but not included in this initial report, villagers that were required to pay for 60% or 40% of their systems (e.g. Las Canas and Las Tejas, in Salama, Baja Verapaz) were more likely to provide proper maintenance to their systems to avoid damaging their investment and begin savings early, thus providing an incentive to ensure long-term operation of the systems. '

Although this is not documented in the used literature on PV systems, the high inflation rate which is common in the studied countries, significantly reduces the incentive to save money for any purpose. Experiences have also shown that users sometimes wait considerable periods of time until they have saved money before calling a technician because they assume they cannot afford repairs, and accept that the system does not work in the mean time.

The ability to pay also plays a role in the user satisfaction. Experiences in Senegal show that user groups paying less for a low quality system were as satisfied with their systems as those groups paying more for higher quality, better functioning systems. It also appeared that the poorer groups opted for solar lanterns and were satisfied with this service, whereas those who could afford a SHS soon invested in this. [Sarr, 1998]

Then the second aspect: willingness to pay, which is closely linked to ability to pay. Willingness to pay is a key aspect of market assessment for the dissemination of PV. Several studies have been performed to assess the price potential PV customers would be willing to pay. The main conclusion that can be drawn from these studies is that people who have not heard of PV systems cannot give a price they would be willing to pay [Green, 1999]. Of course the willingness to pay depends on the (perception of) alternatives. If grid extension is expected, users tend to prefer less financial commitment (i.e. through a fee for service programme).

The willingness to pay down payments or contributions towards service and maintenance strongly depends on user satisfaction. It is in fact seen as a guarantee mechanism, as commonly users stop paying if the system does not function. Also if the service in a fee-for-service scheme is not delivered, several projects have noted that payments stop altogether (Philippines).

The willingness to pay for service and maintenance depends strongly on the value the owner attributes to the system and the investments that the owner has made. This can be seen clearly in a housing project in South Africa, where PV systems 'came with the house'-not leaving the owners a choice whether to buy a SHS or not. Here, the lack of care and maintenance by the

users was obvious [APAS, 1999]. Also in Guatemala an evaluation of five projects shows that there is a clear distinction between the maintenance efforts made by users who had invested in the PV system, and those who had been donated the system. Especially saving for a new battery was apparently a lower priority for the users who had received a free system.
In the Guatemalan example the willingness and ability to pay were strongly linked to system maintenance:
'It is difficult to determine the exact frequency with which families provide maintenance to their system, but in general the system was best maintained in households where it provided maximum benefits (i.e. three working lights, radio/tape player, and or a black and white television). This result reflects both the owner's interest and investment in the system, as well as to the family's economic status.'

The willingness to pay for maintenance also depends on the role of subsidies and donations, in a negative sense. Experiences in Tunisia and South Africa and Guatemala show that users are less willing to pay costs if they are aware of substantial grants for hardware. In these examples, the users had not been required to contribute to the hardware themselves, so that the users may not have felt true ownership of the system.

The payment behaviour also depends on the perceptions of the measures taken in case of payment refusal. If neighbours do not pay and no consequences are noticed, payment stagnates for the whole project.

Finally the willingness to pay for, and the user satisfaction with, the electricity service that can be delivered by PV depends on the perception of alternatives. In Tunisia, users dissatisfaction with the energy service delivered by their relatively large PV systems (104 Wp) is clearly linked to the expectation of receiving access to the national electricity grid. A user is quoted 'at first we refused it' as the village which was electrified with PV at strongly subsidised project, had been waiting for grid connection. In the Philippines, in a project where provision of SHS by the utility was presented as a form of pre-electrification, people stopped paying the fees when the grid was not extended. [Mendoza, 1996a]

5.4 Impact of PV for household use

Income generation
Although developmental objectives such as opportunities for income generation are often mentioned as reasons for rural electrification with PV, there is only limited evidence of the impacts of SHS on income generation. The available evidence shows that the use of the electricity provided by PV for income generation is indirect: examples are mentioned of extended sales hours of local stores and bars, sewing or knitting under PV light in the evening (but with manually powered machines). Also the attraction of tourists is mentioned. In Nepal, 12% of interviewed SHS users even mentioned income generation by attraction of tourists as perceived advantage of SHS. [Schweizer, 1995] The respondents of a recent FAO study on the impact of PV systems for rural development [Campen, 2000] indicate that PV systems do have an impact on productive activities and handicrafts in the evening and longer opening hours of shops for approximately 30% of respondents.

The availability of high quality light in the evening makes it possible to cook or perform other domestic activities in the evening, allowing more time for income generating activities during the day. This effect is stronger on women than on men. In southern Africa (Botswana, Namibia, Zimbabwe, Swaziland, Lesotho the noticed effects are small [Lasschuit, 1999a] [Wamukonya, 1999]. In West Africa, more influence on income generation is noted, with even 10-15% of PV systems being used for indirect income generation in Ghana according to a recent inventory. [Togobo, 2000]

The increase in persons working in production, sales, service and maintenance of PV systems is also a form of income generation by PV. The effects are not clear, however, as for most persons working in the sales, service and maintenance of PV, PV is not the main income-generation activity. It is also argued that the replacement of kerosene and other fuels by PV has a negative influence on the income generation of kerosene dealers. We have found no numbers in literature to quantify actual effects on income generation in this sense.

Energy expenditure

Although the affordability of PV compared to diesel generators or grid connection is one of the main arguments to disseminate PV and for users to acquire a PV system, the energy expenditure does not necessarily compare favourably to a situation without PV.

The amount of money spent on energy for lighting, television and radio, does not always decrease when PV is used. This depends on the extent that PV systems form an additional energy source, or formulated from another perspective: to what extent backup fuels are still necessary, for example for outside use or for rooms where there is no lighting fixture.

Schweizer [1995] reports a reduction of 82% in kerosene consumption and a 15% reduction in dry cell batteries for a project in Nepal. Apparently kerosene is still sometimes used to light the fire and for additional lights, while SHS do not power radios and cassette recorders or torches with the SHS. In Lesotho, the decrease in money spent on kerosene and candles was lower than that spent on PV. In Inner Mongolia [AEPC/ DANIDA, 1999] no reduction was found either.

On the other hand, the installation of converters for the use of radio-cassette is reported to 'give rise to a high satisfaction level of users because it positively impacted the decrease of their expenses on dry cell batteries'. [Zilles, 2000]

In Namibia, the monthly energy expenses of households with SHS is three times that of non-electrified households. As the monthly income of this group is also three times higher, the effect on changes in energy expenditure is not clear.

Time spent to acquire energy for light, television, radio with/without PV system

Households without access to (grid, generator or PV) electricity in the household owning a television generally have their batteries charged at least once every two weeks. Households owning a sufficiently large PV system no longer need to make this trip, saving considerable time and trouble. In fact, this aspect is frequently mentioned as one of the main advantages of SHS. A reduction in necessary frequency of battery transport is even valued, as experiences in Senegal with small PV panels used for partial battery loading show.

Education

The effects on education are unclear. In Nepal, a noticeable increase in children's study time is mentioned [Schweizer,1995] by the researchers, although this was mentioned last as one of the advantages of SHS by the users themselves. Users are quoted on the positive effect of SHS on study in a number of projects [TERI, 2000a]. In the Namibian study [Wamukonya, 1999] the 13% of households that mentioned an increase in time spent studying were mostly teachers who prepared the lessons in the evenings. Other studies find no impact or even a decrease due to switching off the lighting in favour of television [Hammamami, 1999].

Of course an increased access to information can contribute to informal education homework. The impacts are unclear however. Learning effects of the Chinese language are reported [Richter, 1999]: 'for minority nationalities with rudimentary knowledge of the Chinese language, watching television helps improve their language skills. However, for Mongolian women who cannot speak and understand the Chinese language very well, these programmes are not too interesting.'

It is to be expected that general knowledge of the current situation in towns, of the political situation, and of health issues will increase. This is reported by experts in Ghana [Togobo, 2000] and China [Richter, 1999]. However, the actual impacts depend on whether people had access to radio or television before introduction of PV. Generally speaking, the number of televisions grows in areas where PV systems are introduced. In a study in Ghana, [CIDA, 1995] 30% of televisions were bought after PV introduction. The true effect of PV systems introduction is likely to be smaller than can be calculated by counting the number of appliances in homes of PV users before and after PV introduction. A comparison with the increase in number of televisions in a reference area is required for an accurate analysis. The scarce documentation mentioning a comparison shows that PV systems do have an impact on the dissemination of televisions.

Entertainment

Nearly all documents analysing effects on behaviour using appliances report and increase in time spent watching television. Sometimes the lights are even switched off when watching television. Television is sometimes watched with the whole village- so creating a group atmosphere (Ghana). In Mongolia the following effects are reported [Richter, 1999]:

'International and local news are interesting to men and they watch them regularly. Women prefer series, entertainment and Chinese operas. Children enjoy watching cartoons and advertisements. They copy western dancing styles and thus become familiar with international music at an early age.

Most households nowadays spend their leisure time watching television. The time spent watching television is related to the power supply per day and can amount to up to five hours. As the number of televisions increased every year, families have a tendency to watch television at home and not with the neighbours anymore. Chatting, visiting neighbours and playing cards, now play a minor role as evening activities. Here a definite change in social life and communication patterns can be observed.'

Sleep

The reported effects on sleep vary from hardly any effects [Schweizer, 1995] [Zilles, 2000] to 4 hours decreased sleep. The research results of Wamukonya show a decrease in sleep of 1.5 hours for 59% of women and 71% of men. Stories in Ghana show a larger effect on decreased hours of sleep for women, to as low as 5 hours per night.

People get up earlier in the morning to go to work, or spend a larger part of the day in income generating activities [Campen, 2000].

Health

Positive health effects from PV systems could be a result of cleaner air following from the substitution of kerosene or candles by PV light. Health impacts such as decreased eye irritation from soot particles (for children who spent considerable time studying with kerosene light) are not obvious to end users, however [Wamukonya, 1999] [TERI, 2000b]. End-users interviewed for these studies did not understand the issue or found it ridiculous. The lack of confirmation in these studies implies that the change in indoor air quality is much more dependent on the cooking fuel and devices than on lighting.

As far as we know, there are no research results on the occurrence of accidents with fire or batteries. It seems that leakage of batteries does not occur frequently enough to be mentioned as a health hazard, although the risks of polluting drinking water due to inappropriate battery disposal are mentioned [Togobo, 2000]. The safety of PV lighting compared to conventional kerosene lanterns and candles is frequently mentioned, (especially high-pressure kerosene lanterns form a high fire-risk according to Schweizer [Schweizer, 1995].)

Safety

SHS increase the perception of safety. Lights are experienced as a safeguard against theft, and increase the sense of safety in the streets. This effect is mentioned in nearly all social impact studies. There is a demand for small lights that can be left on all night for this purpose- as experiences in Indonesia and Brazil [Zilles, 1997] show. Lanterns are also valuable for the sense of safety when it is necessary to leave the house at night, for instance when going the toilet. Protection against wild animals is mentioned as an advantage of SHS [Schweizer, 1995].

Comfort
The easiness in handling of PV light, and the cleanness are advantages of SHS lighting above kerosene lamps. These improvements in comfort are generally valued by the users, with 27% mentioning easiness of handling and 34% mentioning cleanness in the study performed in Nepal [Schweizer, 1995].

Status
SHS contribute to the status of the households owning them, especially in areas where not all households can afford a SHS. In Nepal [Schweizer, 1995] 'the reputation of the village rose compared with the surrounding villages that have to 'stay in the dark'.'

Social disparity
Although rural electrification is commonly seen to have a developmental impact on rural areas, negative side effects can be observed. In those cases where the poorer segments of the population do not have access to PV, social disparity can be enhanced. This is most noticeable in the status and flexibility PV systems offer, but also in the time spent in transporting batteries or also in finance. Even though substitution of traditional lighting or battery charging services by PV systems may be cheaper on the long term, poor households cannot usually afford to invest in the long term and are therefore forced to continue the higher energy expenditure. (This effect is not marked, as it appears that PV systems usually do not completely substitute traditional energy sources)

Migration
Having a PV system does not seem to have an effect on migration The reasons for migration to cities are possibilities for education of children and income generation, and PV has hardly any influence on either of these aspects. The size of PV system does not make a difference [Richter, 1999] [Wamukonya, 1999]. Richter makes the following remarks:

'Reasons for migration to towns are better schooling possibilities for children and better job perspectives for other household members. Today the availability of electricity offer neither, and therefore, hardly reduces migration.
Although the installation of the renewable energy systems definitively improves the quality of life and the living standard of the rural households, it's effects on underemployment, poverty alleviation and migration should not be overestimated. The capacity provided by the systems is just not enough.'

In areas where PV seems to have a larger impact on income generation, the effects on reducing migration from rural areas seems to be larger [Togobo, 2000].

Environmental impacts
The environmental impacts of Solar Home Systems are generally not a major issue for projects or programmes, or for the owners of SHS themselves. The battery is the only component that does receive some attention. This is important, as in some cases (Ghana) it is feared that the contents of waste batteries which are disposed of without attention for the environment will leak to the drinking water. The problems that can follow from improper disposal of batteries are not commonly known [Togobo, 2000]. A quote form Nepal: [AEPC/ DANIDA, 1999]:
'Asked about battery management plan in the future, more than half of the participants said that they did not know about this matter, [...] Few respondents said that it could be replaced and some other were of the opinion that it could be thrown away or burnt' .

In countries where recycling of batteries is common (India), the negative environmental impacts of SHS are likely to be smaller. However, we have little information on the recycling of batteries in rural areas.

5.5 Conclusions

Because the number of influencing factors on the users experience and on the impact of PV are so large, it is hardly possible to make generally valid statements on these issues. However, based on a number of detailed case studies, it is possible to identify the most important factors of influence.

Evidence shows that the income of users on the commercial market is generally higher than that of users identified through projects, although the number of systems bought on the commercial market by relatively well-off relatives of the end-users is not to be ignored. Other common characteristics of end-users are employment in agriculture and small trade or tourism, city-related employment with regular income and the familiarity with charging batteries. Within a household, women are generally the main users of the PV system.

The user satisfaction depends on the provided energy service, the user understanding of the system, the availability and quality of maintenance and service, and the ability to pay. Some remarkable findings on these subjects are:

- Programme implementers have a ‘technology-fix’- viewing problems too much from a technology perspective rather than from the user;
- users of larger systems are generally more satisfied,
- satisfaction does not depend on the cause of dysfunctioning, however technically complicated or simple the problem may be;
- the number, location and type of lights in a SHS kit often is not adapted to users’ requirements;
- the low awareness of PV system functioning hinders a wider market introduction;
- seeing working PV systems is the best advertisement, followed by ‘word of mouth’;
- the absence of a (functioning) maintenance or service scheme or the costs of such a service is one of the main causes for complaints;
- costs of SHS range between one tenth and half of the annual income of users on the commercial market;
- a selection of users on criteria of ability to pay (including for maintenance and replacements) is beneficial for the success of credit schemes, fee-for service, and, importantly maintenance of the systems and replacement of parts;
- the willingness to pay and how users value their PV systems depends strongly on the (perceived) alternatives.

The second main topic of this chapter was the impact of SHS on users’ lives. It is remarkable that the perceived and often quoted impacts by programme and project implementers are more often than not different from those perceived as most important by the users themselves.

The most cited impact of PV: rural development through increased opportunities for income generation, only occurs indirectly and at a limited scale. Income generating activities make indirect use of the electricity provided by PV- mainly through light. Most common income generating impacts are for extended sales hours of local stores and bars, sewing or knitting under PV light in the evening (but with manually powered machines) and the attraction of tourists.

Another perceived impact, reduction of energy expenditure, is not backed up by literature. The amount of money spent on energy does not necessarily decrease when PV is used, depending on the need for additional and backup fuels and especially dry batteries.

The perceived impact on education is not clear- depending on priority given to television or study, and on the access to television and radio prior to PV.
In line with the limited impact found on income generation and education, the impacts on migration from rural areas to cities is also smaller than perceived from many project objectives.

The most important impacts from the point of view of most users are reduced time and effort for battery charging, possibilities for entertainment, income generation, increased comfort and safety.

All in all, one can conclude that there are more positive impacts than negative, but that the expectations are often higher than can be met by PV.

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6. CONCLUSIONS AND RECOMMENDATIONS

In the preceding chapters the findings are presented from the different literature sources. Often, they are formulated as conclusions. There is no need to repeat them here. In this chapter general conclusions (in standard font) plus recommendations (*in italics*) are formulated. There is more own interpretation of team members in this chapter than in the previous five.

Conclusions and recommendations[4]
The main conclusion is that there is not enough information available about the performance of solar home systems and projects. This hampers further development. In more detail the following conclusions can be drawn:

1. Hundreds of solar home systems projects have been conducted in the past few years. For a considerable number of these, descriptions of the organisational set up exist. However, only very few studies describe in some level of detail how solar home systems are actually used by households. Some early successes might have given the impression that everything is running well and there is no need to spend time and money in this stage on further research. But relatively high failure rates, even in recent projects prove that there is still scope for improvements. More information is required to organise better dissemination activities, to decrease the default rate in credit schemes, and to improve the quality of hardware and installation of systems. *To increase insights into the use of solar PV in households, monitoring and evaluation activities are required, using as main instruments, data loggers and household surveys.Monitoring needs to be continued after solar home system projects end.*

2. Establishing a viable distribution and servicing infrastructure appears to be one of the weakest parts in the dissemination chain for solar home systems at the moment. There are very few entrepreneurs that take the risk to establish a solar PV distribution and servicing company. *Strengthening this infrastructure is necessary, for example by supporting human resource development in small and medium scale enterprises. A flexible instrument needs to support existing entrepreneurs in receiving training to manage companies, advise in selecting a product and service range, and financial support for investments in stocks and establishing service stations. Existing initiatives need to be supported instead of creating a new source of entrepreneurs.*

3. In countries with a commercial market for solar PV systems for households, extreme care is required in using hardware subsidies to support dissemination of PV systems. Subsidies can distort markets by providing unfair competition, especially to small start-up companies in production and distribution. *To limit possible negative effects on local production of BOS components, hardware subsidies can best be directed to the module only and have a ceiling determined by price differences on the local market.*

4. Projects supporting a single type of solar home system should be avoided as far as possible. The largest density of PV-systems in an area can be attained if people have a choice in system It is especially important to include smaller module capacities in the range of 10-30 Wp as well. *The viability of a distribution and servicing infrastructure can be enhanced by including solar lanterns and solar battery charge stations in solar home system projects. Wishes of the user concerning the number and location of lights and suitability for other appliances must be taken into account.*

[4] Recommendations 1, 2, 8 and 9 were presented and discussed in a workshop in Utrecht on 17 May 2000. There was general support for 1, 2 and 8. Recommendation 9 was rejected by the participants of the workshop. Recommendation 10 was suggested by one of the participants, and this received support of a majority.

5. Institutional models for the dissemination of solar home systems are often exclusive. In a limited geographical area, the private sector market usually does not flourish if similar systems are distributed in government programmes with heavy subsidies. Often existing programmes have a historical basis and are suited to local conditions. *Under these circumstances it can be more beneficial that external support focuses on strengthening existing programmes than to support completely new activities that compete with existing programmes.*

6. The fee-for-service system is a promising mechanism from a sustainability point of view However, there is only limited information available about the pros and cons of this scheme. *Careful monitoring and evaluation of fee-for-service systems in different countries can contribute to make it a success.*

7. Credit schemes are useful to improve affordability and thereby increase access of middle income households. An alternative to reach this consumer group can be the use of smaller, modular systems. *Monitoring and evaluation of solar home systems that are sold piecemeal instead of in kits will contribute to more information about the characteristics of this market, allowing for design of better products and more efficient marketing. Replacements and maintenance must be affordable and available for end-users.*

8. The limited information available about experiences with PV for households is often difficult to access and is scattered over different sources. Especially reliable and non-biased information about experiences from the perspective of the user is scarce. This information is extremely valuable to improve design of new projects. To facilitate exchange of information, a database with project information is very useful. *We recommend maintaining and extending the database with information about projects and markets.*

9. Batteries and fluorescent lights are the two components with the most frequent failures in solar home systems. Protection of the battery can be enhanced by improved charge regulators, which are currently of simple design. Also the quality of the production process is often low. *To enhance product quality, improved designs of fluorescent light inverters and charge regulators need to be developed. Companies need assistance to improve their production processes through training and support in establishing joint ventures.*

10. Markets are not sufficiently transparent at the moment. Good products are available, but users need information to make their choices on the basis of price-quality ratio. *The role of end-users needs to be strengthened by empowering end-users for example by having independent consumer organisations compare the different products on the market.*

11. Countries with government support for solar home systems, often apply sets of requirements for systems and components to become eligible for inclusion in programmes. However, we could not obtain evidence that systems in countries with these requirements perform better than systems in countries without government requirements. *Field monitoring, complemented with laboratory tests are required to achieve a stronger feedback from experiences with actual quality in the field towards formulation of standards and requirements by national governments as well as IEC and PV-GAP.*

ANNEX 1. RESULTS: COLLECTED INFORMATION AND THE DATA BASE

Documents on experiences with solar home systems

In the framework of this study, almost 400 documents on experiences with solar home systems in the field were collected. Additional information was obtained in trips that were made by team members to Germany, Ghana, Kenya, South-Africa, The Philippines, Indonesia, Cuba, Mexico, Guatemala, Argentina, Brazil and Honduras (see Annex 6 to 8 for reports of the visits to Latin America).

The list of collected documents is impressive. By using the various approaches for searching information as described in Section 1.6, we have been able to find the most of the major projects for which written information is available. However, it appears that there are two important limitations to our approach to evaluate projects by means of written information.
One major limitation is the existence of written information. Very few reports and articles describe activities of commercial dealers who distribute systems on cash sales. Furthermore, for particular countries or regions, experiences with projects are not very well documented on paper, for example for China and Latin America. Usually, no written information of ongoing projects exists yet.
A second major limitation is the quality of the evaluations. It is not common practice to monitor project results. Monitoring is seldom part of a project. If a project is monitored, evaluation is often done in the first two years. Considering that technical problems with batteries usually start to occur after three years, an evaluation period of two years is too short to demonstrate the long-term sustainability of a project. In addition, monitoring and evaluation is often not done by independent parties: as a result, most documents are not very critical and explicit about the experiences in the project. For various projects, we requested additional information from persons involved with the project. However, these attempts were not successful in the limited timeframe of this study.

The RSVP-ECN database

We put data of 104 projects in the RSVP-ECN database (see Annex 2 for a complete list of the projects). Some of the publications in the list were received too late to be included in the database (and are also not included in following analysis).

The RSVP-ECN database contains as the following main data categories: 1) Basic project data; 2) Technical data of the systems; 3) Economic data of the project; 4) Data on the host country, and 5) Lessons learned (see Annex 3 for a complete list of items in the RSVP-ECN database). Usually, the publications contain much information about the basic data, some information about technical and economic data, and hardly any information about the host country. Information about the lessons learned is often limited to a few loose remarks but can also be totally absent. We estimate that on average about one third of all items in the database can be filled in for a project with the information from the collected publications. The quality of the information in the database could be improved (and the amount of information could be increased) by having it checked by someone involved in the project: this has not been done for this study. Further analysis with the data base is possible.

The main characteristics of the projects in the database are shown in Figures 1 to 10. They can be summarised as follows.

- *Project type*: More than half of the projects are pre-commercial or government projects. Slightly more than 10% are commercial projects.
- *Project region*: About 40% of the projects is in Latin America and also about 40% in Africa; most of the rest is in Asia.
- *Type of user:* All projects are directed towards individual households; in 16% of the projects systems are also used by entrepreneurs, communities, clinics or schools.
- *Participants:* In 44% of the projects, the private sector was not involved. In many projects, governments, international or bilateral donors, NGOs, cooperatives participate.
- *Ownership:* Ownership (in case of credit after the loan has been paid) by end-user occurs in almost two-third of the projects; experiences with other types of ownership are limited.
- *Main application:* The main application for solar home systems is lights, radio and television. 25% of the systems is used for lighting only. Productive use occurs in some cases.
- *Type of system:* Distributed systems are most common. Dedicated systems are seldom used.
- *Project size:* Half of the projects deal with 100 to 1000 systems. There are a few projects with more than 10,000 systems.
- *Start date:* The emphasis in the database is on projects that started between 1991 and 1995 (46%) and 1996-2000 (33%).
- *Institutional model:* The institutional models of the projects can be listed as follows in descending order of occurrence: credit (54%), fee-for-service (16%), donation (16%), cash or credit (8%) and cash (6%).

For the reasons mentioned earlier, these values are not representative for all the various projects that have been done world-wide up to now.

Conclusions

We conclude that our approach to obtain written information about experiences with solar home systems gives a good overview of the many projects and various approaches that have been used for the implementation of solar home systems. However, the quality and amount of the collected information is not sufficient for a systematic evaluation of the projects and the lessons learned. As a consequence, we are not able to perform a thorough statistical analysis of the projects. In the rest of this study, we will analyse projects by searching the publications for clearly reported or conspicuous experiences. To this end, we have put the information of 104 projects in the RSVP-ECN database.

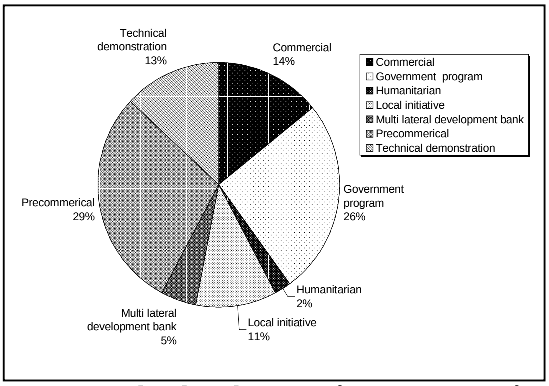

Figure 1: The distribution of project types for the 85 projects (out of 104) in the database for which the project type was specified.

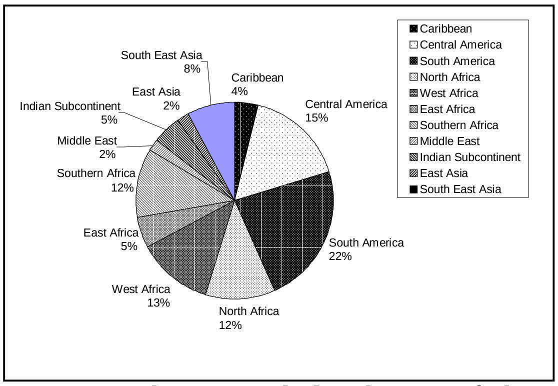

Figure 2: The regional distribution of the 104 projects in the database.

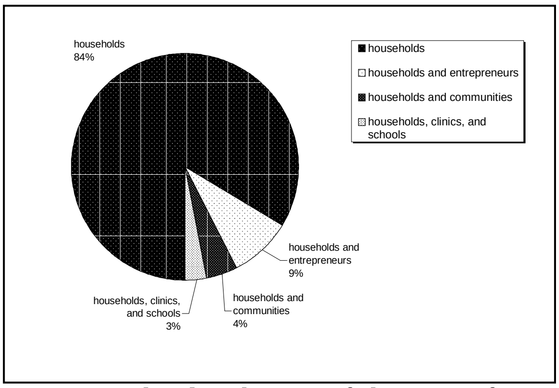

Figure 3: The distribution of the type of user in the 67 projects (out of 104) in the database for which the type of users was specified.

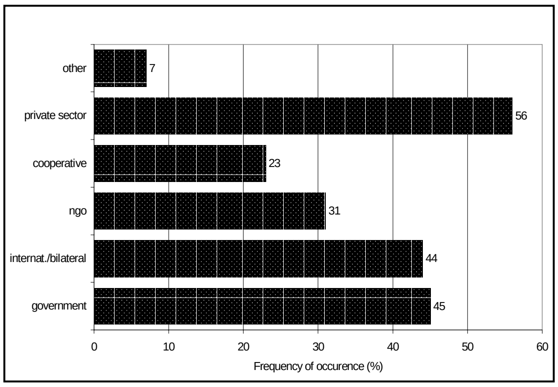

Figure 4: The frequency of occurrence of participants in the 80 projects (out of 104) in the database for which the project participants were specified.

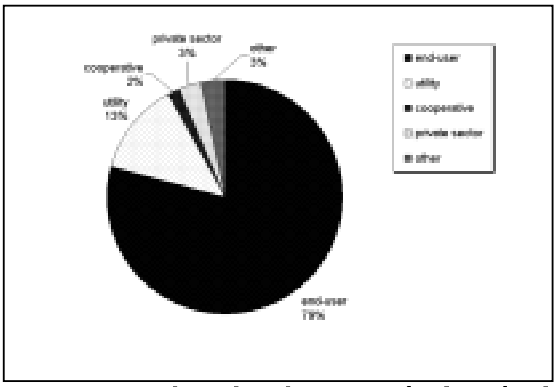

Figure 5: The distribution of the final ownership of the systems in the 62 projects (out of 104) in the database for which the ownership was specified.

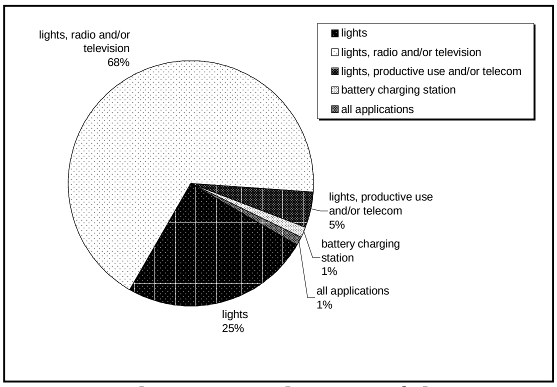

Figure 6: The main application of the systems in the 84 projects (out of 104) in the database for which the main application was specified.

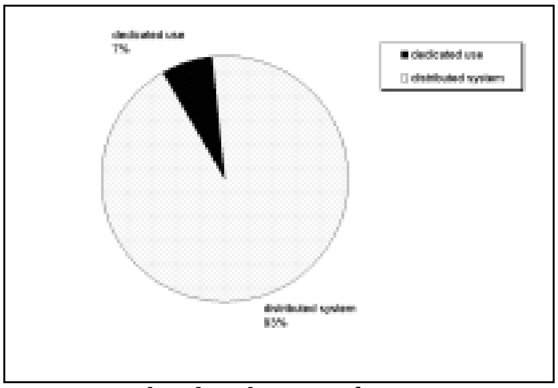

Figure 7: The distribution of system type in the 90 projects (out of 104) in the database for which the system type was specified.

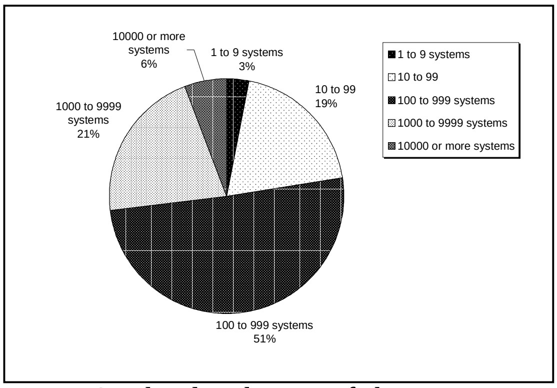

Figure 8: The distribution of the project size in the 70 projects (out of 104) in the database for which the project size was specified.

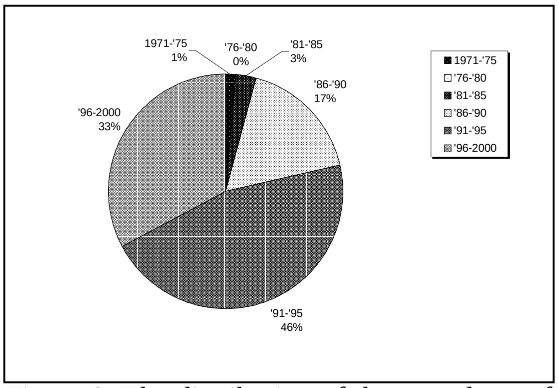

Figure 9: The distribution of the start dates of the 70 projects (out of 104) in the database for which the start date was specified.

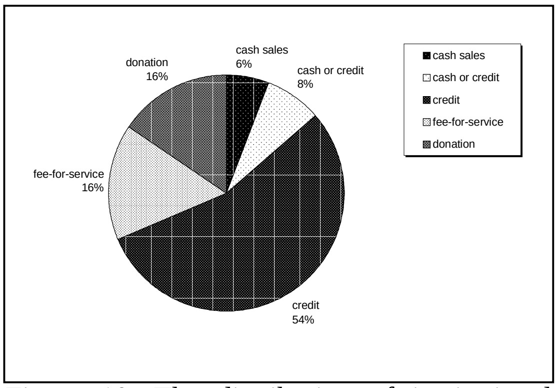

Figure 10: The distribution of institutional models for the 51 projects (out of 104) in the database for which the institutional model was specified.

ANNEX 2. PROJECTS IN THE DATA BASE

Table 1: List of projects in the database (May 31, 2000). An asterix in the project name indicates that some basic data but no details of the project are available.

	Country	*Project Name*	*Project Date*	*Num-ber of instal-led sys-tems*	*Project Type*
1.	Argentina	Argentina: Jujuy, PV installation by private concessionary	1996 -	721	government program
2.	Argentina	Argentina: La Rioja, GTZ-El Dorado*			multilateral development bank investment
3.	Argentina	Argentina: La Rioja - Fundacion para la Revolucion Productiva*			local initiative
4.	Argentina	Argentina: Provincial Initiatives in Nuequen*			government program
5.	Argentina	Argentina: Saltas, PV installation by private concessionary*			
6.	Bangladesh	Bangladesh: Grameen Shakti SHSs for Microentrepreneurs	1996	607	precommercial pilot
7.	Bangladesh	Bangladesh: Narsingdi solar home systems	1993-1997	1370	precommercial pilot
8.	Bolivia	Bolivia: Rural elctification of Bolivian High Plateau	1988-1993	1000	technical demonstration - check
9.	Bolivia	Bolivia: NRECA-COAINE energy co-operatives		100	
10.	Bolivia	Bolivia: NRECA-CRE: Electrification Fee for Service		1000	multilateral development bank investment
11.	Bolivia	Bolivia: Cochabamba electrification		50	
12.	Bolivia	Bolivia: Luz del Sol (Inti K anchay)		500	local initiative
13.	Botswana	Botswana: Manyana renewable energy technology demonstration project	1991	48	technical demonstration
14.	Brazil	Brazil: CESP Valle do Ribeira - ECOWATT Program	1997 -	120	commercial
15.	Brazil	Brazil: USP/UPM User association program Sao Paolo State	1995	15	local initiative
16.	Brazil	Brazil: Lig Luz Rural PV, COPEL	1997-	403	precommercial pilot

17.	Brazil	Brazil: Minas Gerais PV development activities - CEMIG	1995 -	42	precommercial pilot, technical
18.	Brazil	Brazil: PRODEEM Rural development programme	1994-		government program
19.	Brazil	Brazil: Pernambuco PV Pilot Luz do Sol	1994	345	government program
20.	Brazil	Brazil: Ceara PV Pilot - COELCE	1994	470	government program
21.	Brazil	Brazil: Norte de Minas, village/ NGO PV initiative*			local initiative
22.	Brazil	Brazil: Valente, Minas Gerais, community initiative*			
23.	Brazil	Brazil: COELBA PV installation in Bahia*			
24.	Chile	Chile: Camarones PV electrification		149	government program/ humanitarian
25.	China	China: Hua De Company systems in Inner Mongolia			
26.	Costa Rica	Costa Rica: Guanacaste cooperatives*			
27.	Dominican Republic	Dominican Republic: PV Case Study			
28.	Dominican Republic	Dominican Republic: SOLUZ leasing of SHS*			commercial
29.	Dominican Republic	Dominican Republic: ENERSOL 1993-2000*			
30.	Dominican Republic and Honduras	Dominican Republic and Honduras: Micro Credit for Renewable Energy Enterprises	Since 1984 in DR and 1991 in Honduras		precommercial pilot
31.	Ghana	Ghana: CIDA, UR/UST Renewable Energy Project	1995-1999	20	precommercial pilot
32.	Ghana	Ghana: UNDP/GEF			precommercial pilot
33.	Ghana	Ghana: Kpasa off-grid rural electrification project	1998		government program
34.	Ghana	Ghana: ISOFOTON project*	1998	400	
35.	Guatemala	Guatemala: Genesis PV Rural Electrification	1993		humanitarian
36.	Guatemala	Guatemala: Buena Ventura Solar Electrification	1992		precommercial pilot
37.	Guatemala	Guatemala: Zacapa - PLAN International	1995 -1996	151	local initiative
38.	Guatemala	Guatemala: Ministerio de Energia y Minas*			government program
39.	Guatemala	Guatemala: NRECA methodology; from schools to individual SHS*		3000	local initiative
40.	Guatemala	Guatemala: San Buena Ventura pioneer PV project*			
41.	Guatemala	Guatemala: GENESIS credit scheme*	1996		local initiative

42.	Honduras	Honduras: CADETT: Promoting rural electrification in Honduras*	1994	100	local initiative, commercial
43.	Honduras	Honduras: SERNA initiatives towards rural electrification*			government program
44.	Honduras	Honduras: ADESOL/ ENERSOL solar electrification*			
45.	Honduras	Honduras: SOLUZ leasing of SHS*		200	commercial (?)
46.	India	India: Ramakrishna Mission Project	1994	290	government program
47.	India	India: SELCO Photovoltaic Electrification vt. Ltd.	1994	1000	precommercial pilot
48.	Indonesia	Indonesia: WB/GEF Solar Home System Project	approved 1997; 5 years duration	200	multilateral development bank invest., precommercial pilot
49.	Indonesia	Indonesia: Lebak Solar Home Systems Project	1991	420	
50.	Indonesia	Indonesia: Sukatani PV	1988-1989	102	technical demonstration
51.	Indonesia	Indonesia: AusAID/Indonesia Solar Home Systems Project	1997	36400	government program
52.	Kenya	Kenya: SHS in Bubgoma, Ol Kalou and Maranga		91	multilateral development bank investment
53.	Kenya	Kenya: Amorphous Silicon Systems	1999	145	commercial
54.	Kenya	Kenya: Global Lighting Services for the Poor Phase II	1997		precommercial pilot
55.	Kenya	Kenya: 410 Solar Home Systems in 12 Districts in rural Kenya	1996-1997	410	commercial
56.	Kenya, Niger	Kenya and Niger: marketing tests of solar lanterns in the rural areas	1997	520	commercial
57.	Mali	Mali: PSE*	Before 1994	250	precommercial pilot
58.	Mali	Mali: commercial dissemination*			commercial
59.	Mexico	Mexico: Rural electrification as part of Federal poverty alleviation program	1989-now	75000	government program
60.	Mexico	Mexico: Los Sabinos rural electrification			technical demonstration
61.	Morocco	Morocco: Renewable Energy Supply Concept (SAER)	1988-1993	600	precommercial pilot
62.	Morocco	Morocco: government programme PERG-KfW	1996-1998		government program
63.	Morocco	Morocco: PPER first phase	1994		precommercial pilot
64.	Morocco	Morocco: commercial		50000	commercial

		dissemination*			
65.	Namibia	Namibia: Rural Namibia, which way to go?	1997-	350	government program
66.	Nepal	Nepal: Commercial distribution of SHS in Nepal		2000	commercial
67.	Nicaragua	Nicaragua: Government/ INE activities*			government program
68.	Nicaragua	Nicaragua: FENIX, recycling of solar panels*	1996		local initiative
69.	Nicaragua	Nicaragua: ECAMI project*			
70.	Niger	Niger: ESMAP/GEF	1996/1997	200	precommercial pilot, technical demonstration
71.	Peru	Peru: Lago Titicaca do Punos rural electrification	1995-now	146	technical demonstration
72.	Peru	Peru: Proyecto Solsistemas	1986 -?		
73.	Peru	Peru: PV Electrification of the forest community of San Fransisco	1998-?	114	government program, commercial
74.	Philippines	Philippines: Belance Solar Electric Project (BELSOLAR)	1993	100	precommercial pilot
75.	Philippines	Philippines: Ileco III project	1992-1995	150	government program
76.	Philippines	Philippines: Ileco II project	1992-1995	47	government program
77.	Senegal	Senegal: projet Senegalo-Allemand Energie Solaire phase 1	1987-1994	1589	precommercial pilot
78.	Senegal	Senegal: project Senegalo-Allemand Energie Solaire phase 2	1995-1998	699	precommercial pilot
79.	Senegal	Senegal: battery charging stations*			
80.	Senegal	Senegal: ADEME-NAPS*	1994		technical demonstration
81.	Senegal	Senegal: Fonds National de l`Energie CGE*		55	
82.	Senegal	Senegal: commercial market*	1986-1998		commercial
83.	South Afrcia	South Africa: PV installations in Soshanguve	1988	1197	commercial, local initiative
84.	South Africa	South Africa: Benefits and impacts of SHS: A case study	1995		
85.	South Africa	South Africa: PV System Evaluation for the Qua-Qua housing project	1991	9	technical evaluation
86.	South Africa	South Africa: Folovhodwe Solar Home System Village Project	1997	582	precommercial pilot
87.	South Africa	South Africa: Kwabhaza energisation project	1997	80	precommercial pilot
88.	South Africa	South Africa: Maphaphethe SHS dissemination project			government program
89.	Swaziland	Swaziland: Review of the PV market	1985	1200	commercial

90.	Syria	Syria: demonstration of SHS for the Bedouin	1998-1999	4	technical demonstration
91.	Thailand	Thailand: national PV programmes	1971 -	50000	government program
92.	Tunisia	Tunisia: National Programme first phase	1993-1996	1000	technical demonstration, precommercial pilot
93.	Tunisia	Tunisia: National Programme second phase	1994-1999	1250	government program
94.	Tunisia	Tunisia: National Programme third phase	1995-1999	1000	government program
95.	Tunisia	Tunisia: SEP Pilot projects	1989-1992	90	precommercial pilot
96.	Tunisia	Tunisia: National Solidarity Fund	1995	1000	humanitarian
97.	Tunisia	Tunisia: SEP intermediate phase project	1992	30	precommercial pilot
98.	Tunisia	Tunisia: Ouled Nouaouia project	1990-1992	65	technical demonstration
99.	Tunisia	Tunisia: Dhokkara project	1993	45	
100.	Vietnam	Vietnam: SOLARLAB activities	1989-	800	precommercial pilot
101.	Yemen	Yemen: World Bank/ ESMAP project	1990-1993	260	precommercial pilot
102.	Zimbabwe	Zimbabwe: BUN Equivalent Solar Home Systems	1996-1998	149	precommercial pilot
103.	Zimbabwe	Zimbabwe: Study on promotion of PV in rural electrification	1997-1998	112	precommercial pilot
104.	Zimbabwe	Zimbabwe: Zimbabwe PV for household and community use project	1992-1995	1500	government program/ mulitlateral

ANNEX 3. FORMAT OF INFORMATION IN DATA BASE

BASIC DATA

GENERAL

Project Name	
ID1	

BASIC DATA

Abstract	
Project Name	
Region	(Choose one: Caribbean; Central America; North America; South America; Central Africa; East Africa; North Africa; Southern Africa; West Africa; East Asia; Indian Sub Continent; Middle East; Pacific Islands; Southeast Asia; Eastern Europe; Newly Independent States; Australia/New Zealand)
Country	
Location within Country	
Technology	Photovoltaics
Sector	(Choose one: Commercial; Residential)
Main Application	(Choose one: Battery Charging Station; Computer; Lights; Lights, Radio, Television; Power Tools; Refrigerator; Sewing Machine; Radio; Television; Video; Other)
Project Type and Characteristics	(Choose one: Commercial; Government Program; Humanitarian; Local Initiative; Multilateral Development Bank Investment; Precommercial Pilot; Technical Demonstration)
Type of Systems(s)	(Choose one: Dedicated Use; Distributed System(s))
Project Date(s)	
Project Status	(Choose one: Planned; Underway; Functioning; Looking for Financing; Defunct)
Lead Organization	
Last Updated	

Goals and Objectives

Developmental Objectives	(Choose all that apply: increased options to spend the evening through improved quality of lighting; increased quality of health through improved quality of indoor air; increased communication and education possibilities (radio, tv, light); increased safety through light; increased possibilities for income generation of end-users; job generation through supply, sales and service within or following from the project; other (define); no specific developmental objectives defined in projec
Environmental Objectives	(Choose all that apply: CO_2 reduction; reduced battery waste; other (define); no specific environmental objectives defined in project)
Institutional Objectives	(Choose all that apply: increased knowledge and experience on 1) organisational structures; 2 financing mechanisms; 3) technology; 4) influence of improved access to electricity; other (define); no specific institutional objectives defined in project)

Project Size

Systems installed (number, Watt size, and type	
Total number of systems installed	
Total costs	

Users	(Choose all that apply: habitants, households communities, entrepreneurs)

INSTITUTIONAL ASPECTS

Project Participants

Government Agencies
International/bilateral Agencies
NGOs (Local and International)
Cooperatives
Private Sector
Others

Project Organization

Organizational Structure (1 ownership; 2 installation, maintenance, service; 3 information and awareness; 4 community involvement; 5 means to achieve developmental, environmental and institutional objectives; 6 other organisational aspects)
Site Identification
Technical Design
Installation
Training
Maintenance
Resource Assessment
Technical Assistance
Community Involvement
Revenue Collection
Follow-up
Other
Links with other projects and programs
Projects origins, history, and development

AVAILABE DOCUMENTATION

Photodocumentation
Project Report(s)
Electronic Archives(s)
Published Article
Vide Tape/Film

CONTACT

Contact
Title
Organization/Company
Address
City
State
Zip Code
Country
Phone Number
Fax Number
Email Address

A. TECHNICAL CHARACTERISTICS

PV

Generator Type	Module Brand, Size (Wp; mean, min, max) and Type (crystalline or amorphous silicon)	Total Number of Modules installed in Project per Brand, Size and Type
1 (Fill in: Photovoltaics) 2 (id.) 3 (id.)		
Additional remarks on PV generators		

Battery

Battery Brand	
Battery AH Capacity (Ah)	
Number of Batteries/System	
DC Bus Voltage (V)	

Inverter

Inverter Brand	

Balance of System

Balance of System(s) Description	

Major Loads

	Type	Number per SHS on average, min, max	Demand (Number of hours per day per SHS on average)
Fixed lighting Lanterns Radio TV (BW or colour)			
Demand Profile (other applications, type)			
Demand Profile Graph			

Technical Performance (only of electrification alternatives)	
Provisions for monitoring and evaluation	

RESOURCE PROFILE

Solar Radiation	
Climate Type	(Choose one: tropical rainforest; tropical savannah; steppe; desert; temperate maritime with dry summer; temperate maritime; continental; snow/high mountains)
Ambient temperature	
Humidity of Air	

Electrification Alternative	(Choose one: Grid Extension; Diesel; Other)
Grid Extension Cost	
Diesel Cost	
Other Cost	

B. ECONOMICS

Economics

EPC Capital Costs (Engineering, Procurement, Construction Per System)	
Cost Recovery Mechanisms	
Contract with End Users (credit Terms and Conditions)	

Financing

Financier	Type	Amount
1		
2		
3		
4		

Financial Description (finance scheme; object of finance (hardware, service, etc.)	
Extent and Role of Subsidies, Tariffs, and Duties	
Economic Rate of Return	
Project Financial Rate of Return	

C. HOST COUNTRY

General

Population (millions)	
GDP per Capita (US$)	
GDP per Capity in Rural Areas (US$)	
Population Density (per km^2)	

Local fuels

	Availability in Project Region	Reliability of Supply	Price (US$/Wh and in Wh per unit)
Auto Battery	(Choose one: common; difficult; not)	(id.)	
Candles	(id.)	(id.)	
Dry cell Batteries	(id.)	(id.)	
Kerosene	(id.)	(id.)	
LPG	(id.)	(id.)	

Local Grid

Availability of Grid	
Plans on Grid Extension in Project Area	
Local Fuel Use: Most Common Energy Use and Appliances	

D. LESSONS LEARNED

PROVISIONS FOR MONITORING AND EVALUATION

Executive Parties
Technical Monitoring
Physical Inspection
Interviews

EVALUATION OF ORGANISATION

Supply/site Identification	(Choose one: good; satisfactory; bad; no opinion)
Technical design or assembly	(id.)
Installation	(id.)
Training	(id.)
Maintenance	(id.)
Technical Assistence	(id.)
Community Involvement	(id.)
Revenue Collection – Repayment time	(id.)
Follow-up	(id.)
Information and Awareness	(id.)
Main Organisational Bottenecks 1	(Choose one: supply/site identification; technical design or assembly; installation; training; maintenance; technical assistance; community involvement; revenue collection - repayment time; follow-up; information and awareness; other)
Main Organisational Bottenecks 2	(id.)
Main Organisational Bottenecks 3	(id.)
Explanation of Main Organisational Bottlenecks	
Potential for Replication and Diffusion	

EVALUATION OF THE TECHNICAL PERFORMANCE OF PV SYSTEMS

Quality of Installation

Quality of Connections	(Choose one: good; satisfactory; bad; no opinion)
Quality of Sizing	(id.)
Orientation, tilt of PV modules	(id.)
Shading of PV modules	(id.)
Distance components to appliances	(id.)

Main Technical Bottlenecks (if any)

Main Technical Bottleneck 1	(Choose one: quality of installation; quality of connections; quality of sizing; orientation, tilt of PV modules; shading of PV modules; distance components to applicances; other)
Main Technical Bottleneck 2	(id.)
Main Technical Bottleneck 3	(id.)

Durability System and Components

System Lifetime (yrs)
Battery Lifetime (yrs)
Regulator Lifetime (yrs)
Other components Lifetime (yrs)
Characteristics Defects in

Components

Modularity

Changes in the initial Configuration (including Appliances) in Time

Safety, Theft, Damage: Occurrence and Consequences

Safety of the use of PV systems (battery explosions, acid leakage, electrical shocks, etc)
Theft
Damage due to external causes (lighting, shading of modules, corrosion, etc.)
Damage due to use/maintenance (car charging; deep discharging from normal appliances, battery maintenance, etc.)
Other Damage Causes

Electrical Performance

Electricity generation
Electricity demand by End Users
Battery Performance

EVALUATION OF THE END USER’S EXPERIENCES
(from the point of view of the user and of the researcher)

Capability to pay monthly fee and reasons
Level of Understanding of the Use of the PV System
Personal Effort to Maintain the System
Changes in the User’s Life due to PV Systems
Complaints and Handling of Complaints
The User’s Own Opinion, among which the Level of Satisfaction

MAIN CONCLUSIONS ON ORGANISATION, TECHNICAL AND USER’S EXPERIENCES

Explain from Objectives of the Project and Social, Economic and Cultural Characteristics

E. NOTES

Notes

F. GRAPHICS

Not in this overview

ANNEX 4. EXPERIENCES IN INDIA

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ABSTRACT

In India over 72% of the one billion population live in rural areas mostly deprived from the basic access to electricity. The huge costs involved in the establishments of power plants and extended grid network coupled with the low load profiles in the rural areas of the country, makes solar power economically viable even at the present high costs. The distributed electricity system with small solar home systems and portable lanterns promises to be the ideal alternative to the other fossil fuel based systems and millions of the kerosene lanterns in use in the country. Market surveys indicate a large potential for solar power and a positive willingness on the part of the users to acquire these systems. The experiences so far indicates increased confidence of people in solar lighting attributed to the improvements in the reliability and the performance of solar lighting systems and has created a wide acceptance. The Governments both have adequately supported this at centre and state levels. The involvement of NGOs (Non Governmental Organisations) in the form of ESCOs (Energy Service Companies) has made possible the introduction of financing and after sales service mechanisms at micro levels to be feasible on a sustainable basis. It is felt that the reduction in costs of PV, the emergence of sustainable NGO/Cooperative institutional mechanisms for micro credit and supply cum maintenance support, duly recognised by the Government, will go a long way in large-scale deployment of solar systems in a meaningful way.

INTRODUCTION

The overall electricity consumption in India is quite low. The national average per capita, electricity consumption for the year 1995-96 was 360 kWh only. There is also disparity in the electricity consumption in the urban and rural areas. About 72% of the population in India live in rural areas and consume only 30% of the electricity. During the last few years due to increasing demand the power shortage is gradually increasing resulting in a frequent non-availability of electricity. An estimated 70 million rural households remain without electricity.

Lighting in rural areas of India is primarily based on grid electricity and kerosene. Although almost 87% of the total 5,80,000 villages have been electrified through the extension of grid electricity, only 31% of the rural households in these electrified villages have electricity connections. Owing to severe power shortages throughout the country, electricity supply is frequently not available during evening hours when lighting is most needed. In this scenario almost all the rural households partially or fully depend on kerosene for lighting. The scenario in the urban and peri-urban area is equally bad with frequent brown outs. Among the villages not electrified so far, about 10,000 villages are remote, far flung and have only small load possibilities. There are about 50,000 villages, which have not been electrified as yet and have population below 500. The remoteness and small loads make grid extension very expensive. (Joyshree 1996, Bhargava, 1998, 1999). Development of loads in rural areas is often slow. Till loads develop the rural electrification projects are not financially viable. The economics of rural electrification is generally unfavorable also due to higher rural grid losses (typically 20%to40%) and the subsidized tariffs.

The bulk of the rural households in India depend on kerosene lanterns for meeting their lighting requirements. There are mainly three types of kerosene lanterns in use. The simple wick type lamp, the hurricane lantern and the pressurised type using a mantle (“petromax”). It is estimated that there are around 100 million kerosene lanterns in use India. These lanterns not only consume fossil fuel and emit carbon dioxide but also provide insufficient and poor quality light. In addition to the kerosene lanterns, battery operated lights are also in widespread use for intermittent and limited lighting requirements.

In India with most of the areas receiving good solar radiation throughout the year, solar photovoltaic powered household lighting systems represent a clean, climate-friendly viable solution to meet rural lighting needs. Solar lanterns which are essentially a solar powered portable lighting system are considered to be a viable alternative to the kerosene lanterns to meet the growing lighting needs of villages and remote areas. (Bhargava and Sastry, 1992) The light output from a solar lantern is much higher compared to the light output of a kerosene lantern. Though the petromax is considered to be most efficient among all the kerosene lamps the hurricane lamps are most commonly used. Typically light output of a kerosene lantern is about 68 lumens against solar light, which produce about 450 lumens. An average daily use of 4 hours of hurricane lantern results in consumption of about 100 liters of kerosene every year.

SOLAR PV PROGRAMMES IN INDIA

The solar photovoltaic (PV) programme in India was initiated in 1975 by the Department of Science & Technology of the Government if India. Central Electronics Limited (CEL), a public sector electronics company near New Delhi, was given responsibility for product development while research on solar cells and development of photovoltaic materials was entrusted to the national R&D laboratories and academic institutions. (Mukhopdhyay et al 1992, Sheshdari et al., 1993).

Believed to be the largest PV demonstration programme in the world, the installation of systems in India is impressive. Much of the rural PV installations have occurred, however, as a direct result of the demonstration programs led by the Ministry of Non conventional Energy Sources (MNES) in association with the state nodal agencies, and to a lesser extent, the state electricity boards (SEBs) and non governmental organisations (NGOs). Of the total PV installations (50 MW) in place by Dec.1999, 35% were on a commercial, unsubsidized basis for telecommunications, signalling, defence and similar applications. The remaining were rural demonstrations primarily in domestic lighting, street lighting, power plants, community services and exports accounted for 15%.

The Indian PV market can roughly be divided into two broad segments:
- A government controlled segment
- A private segment

The Government controlled market can again be divided into two main parts:
- A socially oriented scheme
- A commercially oriented scheme

In the socially oriented scheme the Central Government will provide 50% of the ex-factory costs of the PV systems. The rest is borne partly by the state government and partly by the user. Usually the user pays 25% of the total system costs. Manimala et al., 1994) These programme mainly concentrate on lighting. In the commercial scheme, the various organisations under the government such as the department of Telecommunications, Railways etc. are generating large orders for the PV systems.

Solar lantern programme in India
Demonstration of solar lanterns and solar home systems was started in India in 1989-90 and today the Ministry of Non-conventional Energy Sources (MNES) under its solar photovoltaic programme (Sastry, 1994) is supporting activities related to the development and dissemination of solar lanterns and solar home systems in a big way. (Bhargava, 1994, Gopalakrishnan, 1995). The main arguments in support of solar lantern /solar home systems are:

- it provides better quality lighting as compared to kerosene lanterns
- the supply is more reliable compared to grid electricity and makes a villager autonomous as far as availability of light at command is concerned
- being a portable light it can be used both indoors as well as outdoors
- it reduces kerosene consumption and is pollution free
- it provides a variety of options to choose according to requirements and affordability

Till March 2000 almost 2,80,000 lanterns and 1,18,000 solar home systems have been installed throughout the country. Various types of systems are available and the typical configurations are given below:

Table 1: Configurations of solar lanterns and solar home systems in government programmes

Solar Lanterns				
Model	Lamp	Battery	PV Module	System Price (Rs)*
Model I-A	CFL 5W	12 V, 7 AH	8 Wp	3500 –4200
Model I-B	CFL 5W	12 V, 7 AH	10 Wp	4000- 4700
Model II-A	CFL 7W	12 V, 7 AH	10 Wp	4000- 4800
Model II-B	CFL 7W	12 V, 7 AH	12 Wp	4400-5200
Solar Home systems				
Model	Lamp	Battery	PV Module	System Price (Rs)
Configuration I (2 lights)	2*9/11 W CFL	12 V, 40 AH	1*35/40 Wp	14000-16000
Configuration II (2 light ,1 fan)	2*9/11 W CFL	12 V, 60 AH	1*50 Wp	16000-19000
Configuration III (2 light , fan, TV)	2*9/11 W CFL	12 V, 75 AH	2*35 Wp or 1*70 Wp	20000-22000
Configuration IV (3-4 lights & TV)	3-4*9/11 W CFL	12 V, 80 AH	2*35 Wp or 1*70 Wp	22000- 24500

* US $ = Rs.45

At present the initial cost of the PV system is high. The PV modules account for a significant share of the overall cost of a PV system. During the past five years a downward trend in the cost of Photovoltaic modules in India has been experienced. This reduction in cost was possible due to

- Expanded Government supported programme;
- Increasing competition among the PV products manufacturers;
- Incentives provided by the government;
- Increased production volumes; and
- Improvements in the product quality and performance.

SOME IMPORTANT CASE STUDIES

The attempt to popularize solar lighting was started by MNES was taken up in early 1990s. The concern was mainly on the technical aspects and a lot of early development work went to create suitable systems for use in rural areas. Alternate models for battery charging systems were also developed for trials. (Sheshdari, 1993, Sharma, 1993) The focus then shifted to the reliability and costs of systems. , Earlier all attempts were through the nodal agencies. The role of NGOs was appreciated subsequently and NGOs were allowed to play an important role in the MNES programme. The following paragraphs describe some of the case studies.

1. Urjagram – Socio economic impacts, 1993

Urjagram (village with energy) is a project started by MNES in 1983 with the aim to bring about energy self sufficiency in villages by learning locally available renewable energy sources such as biomass, solar and wind. The success of the Urjagram is judged by two parameters, sufficiency i.e. do the devices/ technology meet the felt energy needs of the village and secondly sustainability i.e. does the intervention have a sustainable impact in the long run. The major energy needs are for cooling, agriculture, lighting and space heating. The programme had been implemented in 170 villages by end 1992 and other 225 were under implementation. A large number of solar lanterns and solar home systems were distributed by MNES as a part of Urjagram in the year 1992. The following describes the results of impact study in 1993. (TERI, 1993)

VILLAGE 1

Domestic lights –sanctioned (98), Installed (48/98), of which 40/98 in use.

Table 2: Status of photovoltaic domestic lights in Village 1

Total number of domestic lights	98
Number in use	40
Number not in use	58
(a) Due to tube problem	30
(b) Due to connection/wiring/battery problem	28

During the time of the visit four out of ten streetlights were functioning. The MPUVN (Nodal agency for Madhya Pradesh) officials repair lights which had problems like replacement of tube. By and large, the villagers are satisfied with the lighting system. The following are the benefits perceived by the villagers:

- Children study under this light
- Safeties from wild animals like tigers, bears, wild boars, wolves’ etc.
- Facilities easy movement in the village after dark
- Feeding the cattle

Table 3: Status of solar lanterns in village 1

Number of solar lanterns sanctioned	47
Number of solar lanterns distributed	40
Number of solar lanterns in use	10
Number of solar lanterns not in working condition	30

Table 4: Functionality of solar lanterns not working at present (in village 1).

Developed problems within two months	12
Developed problems within 2-5 months	8
Developed problems within 5-12 months	10
Total number of solar lanterns which have developed problems	30

All the problems solar lanterns developed were connected with short-circuiting of the wiring system.

VILLAGE 2

Solar Lanterns – sanctioned (73), installed (73), 43 in use, 30not in use.
Seventy-three solar lantern of the Kuteerdeep make (Ritika) were distributed in the village to meet the lighting requirements of the villagers. Out of these, 43 were found in use and 30 were not functioning. The villagers were happy with them as they got them free of cost and also they were useful. They stated that the lanterns enable them to save kerosene upto 50%.

VILLAGE 3

PV lantern – sanctioned (50), installed (47), 11 of them were in use and 36 not in use.
47 solar lanterns of the 'Kuteerdeep' make were distributed in the village to meet the lighting requirements of the villagers. These were distributed to only those households who own land in the village. A sum of Rs. 100 was charged for the solar lanterns. Rs. 5 was also to be paid as the maintenance cost, however, none of the villagers paid this amount. Only 11 lanterns were found in working condition during the time of investigation. The rest had developed one or other technical or maintenance problems which neither the villager nor the caretakers could handle. Out of the 30 non-functioning ones. 20 were recently repaired under the warranty period. For these, a sum of Rs. 100 per lantern was charged as repair cost from the beneficiaries. The solar lanterns met the lighting requirements of the households. However, the villagers voiced a demand for a solar PV plant. This is primarily because in a nearby village Lamni (30 Kms away) a solar power plant has been installed with which the residents of Lamni are very happy.

VILLAGE 4

PV domestic lights – sanctioned (20), installed (17), 14 in use
Fifteen domestic lighting systems at Chennai and two at Thalora were installed for domestic lighting. Each system is connected to two lighting points of 9 watts each (PL-9). Fourteen of these systems (28 points) were in use. The beneficiaries purchase distilled water form Udhampur, but S&T staff do the refilling from Jammu. The villagers are satisfied of the domestic lighting system. The benefits as perceived by the villagers are as follows:

- Facilities easy cooking in the night

- Children's studies
- Saving in kerosene
- They feel reliability of this light is much higher compared to electricity from the state electricity board in the nearby places
- Lot of reduction in theft was observed
- Feeding the cattle

Performance of devices
The functionality of different devices under in the fifteen villages surveyed is given. The functionality is that of the installed devices:
PV domestic lights: 58% functional
PV lanterns: 40% functional

The following table summarizes the functionality of lanterns with respect to the suppliers in the fifteen villages.

Table 5: Comparison of performance of different PV lanterns

Description	Kuteerdeep model	Ritika model	Total
Number distributed	87	73	160
Number in use	21	43	64
% in use	24	59	40

NORTH EASTERN STATES

The implementations of SPV schemes are undertaken largely by state nodal agencies, which are energy development agencies and state departments. (TERI, 1998) However, NGOs implemented almost half of the schemes. But the task of implementation assigned to these is mainly through the state nodal agency. (Sharma, 1997) Among the listed schemes, only two were implemented through direct funding from NEC. The schemes that have been executed by NGOs are solar energy utilization in VKO Oyan (Arunachal), Solar energy utilization in Daporijo (Arunachal), solar energy in Umdang (Meghalaya), solar energy in Tarabari (Assam), Employment generation for tribal youths through solar lanterns (Agartala), and Electrification of 4 villages in Manipur. (Sharma et al, 1996)
The state nodal agencies are also responsible for the maintenance of the systems covered under the RRE schemes. However, for schemes implemented by NGOs, maintenance as well as training of locals for the respective areas to rectify minor defects is the responsibility of the NGO. It was observed that maintenance was effectively done at the initial stage i.e. few months after the implementation of the scheme. However, beneficiaries indicated that subsequently no maintenance was carried out. The lack of maintenance is mainly due to the lack of availability of the spare parts and frequently occurring operational problems of the systems. Although the problems encountered have been minor and were easily repairable, but because of ignorance of any kind of maintenance, the rectification was neglected by the users as well as the implementing agency. Thus, systems were damaged owing to long periods of non-functioning.

Functional status of SPV schemes
Most domestic lighting devices were found be nonfunctional owing to the problems in battery, luminaries and electronics. Those in functional status are few because of personal care and maintenance. Solar water purifier suffered from non-functioning of the UV lamp and the batterry. However, no expertise was found for maintaining these systems available at the site.

Solar water pumping systems were also installed but one was found functional. In all systems, solar modules are available at the site but disconnected.

2. Solar electrification in Assam in 1994

The Assam Science Technology & Environment Council (ASTEC) has selected nine very backward villages for taking up a pilot project on electrification by solar Photovoltaics. (Sharma, 1996)
The nearest location of project is 18 KM away from all weather motorable road and 10 Km from the nearest grid power point. A hilly terrain separates the area from the relatively developed Sonapur town and its suburbs. The nine villages with about 400 households are situated within a geographical area of about 20 sq. Km.
The only jeepable road to the project location is travel worthy by vehicle for 3-4 months in the dry season of the year. Eleven Domestic Lighting system and 9 community Lights and TVs were installed during Dec., '94. Failure rate of these systems during last one half year has been as under:

Table 6: Failure rates of components in Assam project

Solar PV modules	Nil
Charge controller	4%
Battery	1%
Inverter (fitted in Luminary)	3%
Lamp	2%
Solar Lanterns-	10%

As the beneficiaries under the project are economically weak the initial contribution have been collected in instalments. So far (Upto Aug'96) Rs. 240,000/- have been collected as initial deposit out of Rs. 368,000/- due.

3. Jaislmer Project 1996

A project was implemented by TERI in Jaisalmer area of Rajasthan as part of a fuel substitution project. (TERI, 1997) Jaisalmer district is situated in the western part of Rajasthan in the Thar Desert with an area of 38,401 km^2; it is the largest district in Rajasthan in terms of area. It has a low population density of 9 per km^2 according to the 1991 census. The district has 519 villages, and according to 1991 census only 40% villages are electrified. Due to very scattered nature of the settlements, electrification through grid electricity is a costly proposition in this area, typically electrification of a village costs Rs 2.5 to 5.0 million.

Four villages Achala, Baiteena, Sanwata and Bhopa were selected for the solar lantern project. Out of these, three villages are unelectrified, and chances of them getting connected to grid electricity in near future are remote. The villages were selected after surveying the area and holding discussions with local government officials and voluntary agencies.

In all 275 lanterns were distributed in four villages. The first lot 150 lanterns were distributed in April 1996 while the second lot of 125 lanterns were distributed in September 1996. The village wise details of lanterns distributed under the programme are given in table 7.

Table 7: Village details of lanterns

Village	Nos.
Baiteena	61
Sanwata	86
Achala	92
Bhopa	33
Others (including lanterns under testing and being used as spares)	3
Total	275

The main feature of the implementation process was the involvement of villagers in the process. To involve villagers, village committees were formed in all the villages. Each village committee has 5-7 members. The committee is responsible for helping TERI team in demonstration and awareness generation activity, collection of dues and managing bank account, record keeping and committee members also help beneficiaries in the maintenance and repair of solar lanterns.

The earlier village committee based maintenance system in which collection of monthly dues and payment of the technicians were being carried out by the village committee was replaced by a new system. The main reasons for the failure of the village committee system were the very high failure rate of the lanterns arising due to poor quality and poor design.

FEEDBACK FROM VILLAGERS

The TERI team members visited all the *dhanis* to collect feedback from beneficiaries and to assess the level and nature of knowledge the users had about the technology and also to provide to them the necessary Know-how on the usage and maintenance of the device. The women are aware of how the technology functions and can operate the device, however the upkeep of the device was not proper for which they were briefed. The technology *per se* was viewed beneficial by a majority of villagers provided it is properly used and maintained. Monetary savings and convenience were highlighted as two factors favoring the adoption of the technology when compared to kerosene. Due to remoteness of the region kerosene supply in the area is not very regular and villagers have to travel up to 50Km to get kerosene supply, in the absence of kerosene villagers use edible oils in their lamps. Due to portable nature of lanterns they are being used outdoors and some families reported saving in the amount spent for dry cell batteries in the torch. The common complaints were: a) the lantern does not give light for required number of hours (minimum 4 hours), b) it breaks down very soon, and c) people do not have easy access to repair facilities: spare parts are not available. (Sameer et al., 1997)
The electronic circuit is not properly designed for 4-pin operation and in 25 lanterns CFL lamps has failed. The major findings of the technical monitoring which were submitted to MNES in January 1997 can be summarised as below:

1. The electronic circuit is not properly designed for operating the 4 pin CFL lamps (in the specifications for solar lanterns for 1995-96, MNES has specified the 4 pin CFL lamps). The four-pin circuit should have a heating circuit for longer life of the CFL lamp. It is suggested that either the circuit is modified for 4 pin operation or it is converted to 2 pin operation.
2. Lack of standardisation has resulted in use of different designs of PCBs (we identified three different types of PCBs in the 275 lanterns supplied to us), which makes interchanging of components in the field a difficult task. Even the sockets type were different and the spare PCBs could not be fitted into the lanterns. It is suggested that PCB design should be standardised at least for a particular make of lantern.
3. Villagers also found problem with the mechanical design of the lanterns (handle comes out, it is very difficult to take out due to defective design. Even if it is taken out, the aluminum rod and bolts give way in two or three operations. This needs total design change.

4. In most of the lanterns the connection between the battery and the rest of the system were found loose (due to poor quality of connectors used) resulting in high-energy losses. Consequently, either the lanterns do not operate at all or operate for much shorter duration (lanterns work for just 1-2 hours compared to 3-4 hours for which system has been designed).
5. The ferrite core has not been properly held in place and overtighting of screw resulted in breakage of core during use. The design of ferrite core needs immediate attention.
6. There are several minor design defects in the system:
   - The fuse body is not held properly and gives way during the replacement of fuses. A notch could be made to secure the fuse in place.
   - Some of the circuits had a missing capacitor.
   - The 4-pin holder used are of poor quality and the lamps sits loose in the holder, loose connection also results in sparking and some of the holders have got damaged due to this reason.
   - The inverter output frequency and voltages showed a large variation, these could be streamlined through quality assurance.

Based on the monitoring results two modifications were made.
- An improved electronic circuit having a preheating circuit for operating four pin CFL was introduced.
- A modified maintenance mechanism was introduced, The responsibility of taking the defective lantern for repair to the shop was transferred to the owner and the monthly collection by the village committee was stopped.

Some of the conclusions, which can be drawn from the experience in Jaisalmer, are below.
- The lanterns have been well received by villagers and many more are looking forward to such programmes.
- However the present design has a poor reliability, design Improves in both electronic and mechanical design is required. Better quality control at the manufacturing level standardisation of components is required.
- Creation of a suitable maintenance system is a prerequisite for the success of such initiatives. More than 400 faults were reported during first nine months of the programme. Keeping in view the high failure rate during the initial period, maintenance should be in place before introducing lanterns in the field.
- Despite, poor reliability of the lanterns, the lanterns have been well received by villagers and many more are looking forward to such programmes. Convenience increased social interaction, better light quality and monetary savings were some of the reasons given for adoption of technology.
- The common complaints were:
  - the lantern does not give light for required number of hours (minimum requirement: 4 hours per day)
  - reliability is poor
  - better repair and maintenance facilities are required

Due to very high failure rates the maintenance system is still not functioning up to the satisfaction of all the beneficiary households. In the absence of local dealers, timely supply of CFL and electronic components is proving to be a problem.

4. Renewable energy for Ladakh Region

Ladakh is a remote region located in the Himalayas with very low population density. Small scattered loads and good availability of renewable energy resources like hydro, solar, wind and geo-thermal, makes the region ideal for renewable energy based decentralized power generation. (TERI, 1996) At present hydro and solar energy play an important role in power generation and rural electrification in Ladakh. Hydro-electricity from small, mini and micro hydro plants (installed capacity 8.5 MW) accounts for about 60% of the total electricity generation. About 7000 solar PV domestic lighting systems (DLS) provides electricity for lighting to about 25% of the households in Ladakh. Solar DLS have proved to be a reliable source of electricity supply in remote villages of Ladakh. (Arne Jacobson, 1997) A survey conducted by TERI in 1996-1997 of the systems installed between 1990-91 and 1996-97 found that around 95% of the surveyed systems were functional.

The highlights of solar DLS programme in Ladakh are:

- <u>Full subsidy</u>: Systems are given free of cost to beneficiary households.
- <u>Implementation approach</u>: Involvement of NGO - Social Works Research Centre (SWRC) in the government programme. SWRC started the dissemination in 1990-91 and used an innovative approach based on demystification of SPV technology for dissemination. A workshop was setup in Leh for the assembly of DLS. (Bunker Roy,1996)While solar panels, batteries and luminaries were purchased from leading manufacturers, electronic circuits (charge controller and inverter) were manufactured locally. The complete system was then assembled locally. Some design modifications were carried out to suit local requirements. Youths from the beneficiary villages were trained in the installation and maintenance of the solar PV systems. SWRC installed solar systems and provided maintenance support through these trained youths. SWRC provided a 10 years maintenance guarantee on the installed systems and in return charged Rs 20 per household per month for the service. Not all the solar DLS systems in Ladakh are installed by SWRC, a large number of systems in recent years have been installed by government agencies – PDD and JAKEDA with the help of manufacturers. However, these systems do not have provision of maintenance support after the first year of operation.

A TERI team conducted a survey of 200 solar DLS in 1996 and 1997. The average age of the surveyed systems was 2.4 years and they had been installed between 1990-91 and 1996-97. The results of the survey are shown in table 8

Table 8: Result of survey of solar DLS in Ladakh

System configuration	35 - 40 Wp module, 6 V/12 V batteries of 40 to 100 A-h, two or three 9 V CFL lamps.
Number of systems surveyed	200
System fully functional	142
Systems partially functional	55
Systems non-functional	3
Average age of the surveyed systems	2.4 years
Average number of daily hours of use	3.1 hr.

The survey showed a high functionality rate for solar DLS and almost 95% of the systems were found to be either fully or partially functional. Most of the users were found to be satisfied with the performance of the technology.

4a. Solar home systems in Leh

A survey covering about 10% of the total number of installed systems in Leh and Kargil districts was carried out to determine the functionality of these devices. The parameters considered in this sample survey were I) installing agency, and ii) year of installation. While the functional status of the systems would be directly linked to the years of functioning, the performance of the system will also reflect on the technical capability of the installing agency, its implementation processes and monitoring and maintaining arrangements.

PV systems are popular among villagers and policy makers. Reasons include low cost per electrified family, short installation times, and a reputation for reliability. Of 200 surveyed systems, 71% were fully functional, 27% were partially functional, and 2% were non-functional. However, the average age of the surveyed systems was only 2.4 years; more failures are likely to occur in time. The short-term success of the systems is in part because government standards require the use of quality components.

PV System Maintenance:
There are two arrangements for maintaining PV systems. The most common is a one-year warranty on parts and labour. After one year these systems generally are not properly maintained, as family incomes are low and no businesses in Ladakh service PV systems or sell the appropriate components.

The Social Work and Research Center (SWRC), a local NGO in the Tilonia school network in India installed approximately 1,000 of the systems. The SWRC has done an excellent job of developing a village level maintenance infrastructure for servicing its PV systems. The program includes an extensive hands-on training program for village technicians. Homeowners pay a monthly fee ($US0.70, covers 50% of the post-technician training maintenance cost) in exchange for a ten year maintenance contract. Most of the SWRC systems are working very satisfactorily due to the availability of local trained technician.

4b. Solar Home Systems in Kargil
According to the information received from the Power Development Department, Kargil; 798 solar home systems had been installed in the district till March 1996. PDD has set a target of installing 601 solar home systems during 1996-97. Most of the installations in the district prior to 1996 were carried out by SWRC, Kargil. However, in the recent years, JAKEDA has been the leading agency in terms of number of systems installed. The project team carried out a survey of 45 solar home systems in village Rangdum (block Taisuru) and village Rantakash (block zanskar). All these systems were installed by SWRC during the period 1994-96. The configuration of the system is follows:

- Village Rangdum: Module 40wp, Battery – 6V, 90AH (2 no), lamp – 9w CFL (2no).
- Village Rantakash: Module 35Wp, Battery – 12 V, 65AH (1no), lamp – 9W CFL (2 no, with one spare CFL).

The size of the systems, both in the terms of module capacity and battery size is larger then the MNES specifications. The large size is justified in view of the higher lighting requirements and low solar radiation availability during winter months and the difficulties in maintenance of the systems in the remote villages. (SWRC. 1999)
Except for two systems, the rest were found to be functional at the time of survey. As in Leh, SWRC collects monthly fees from the beneficiaries for providing regular maintenance services. While in Rangdum a technician trained by SWRC provides maintenance services, the villagers at Rantakash have to travel to SWRC centre at Kargil to get their systems repaired. The systems in Rantakash are provided with a spare CFL to compensate the lack of maintenance support in the village. In Rangdum, SWRC collects monthly charges of Rs 15 per CFL (Rs. 30 per system). Data on faults rectified in the past revealed that the fault in charge controller and writing were the most common faults (reported by the almost all surveyed households) followed by the lamp failure. Most of the surveyed households were satisfied with the performance of the systems.
JAKEDA has an ambitious plan of electrifying 36 villages with solar home systems during the 9th five-year plan (1997-2002). During this period, 3002 solar home systems will be installed in the district. JAKEDA has also formulated a plan to establish a technical backup unit for PV systems at Kargil to carry out the installation, repair and maintenance of the systems installed in the district. However, as per the latest information available the setting up of technical back up units at Kargil has not materialized and at present the systems installed by JAKEDA are without any maintenance support. As a result, there is no provision for collection of monthly charges

from the beneficiary households. This dual approach to collection of monthly charges and provision of maintenance support has led to problems in the villages served by SWRC and some of the users in the villages are unwilling to pay the monthly charges.

Solar photovoltaic home lighting systems have proved to be very successful in fulfilling minimum light requirements of rural households in Ladakh. However in the absence of maintenance and repair facilities, the long-term sustainability of these devices is doubtful.
In 1989, the programme for the installation of solar home lighting systems was started in Ladakh.Till 1997, more than 4000 households were having solar lighting systems. A survey of 262 solar home home systems and 33 solar lanterns in the rural areas of Ladakh was carried out during the study. The results of the survey indicate that:

- Solar lighting systems are a reliable source for providing minimum lighting services in the rural areas of the region. A high percentage (about 95%) of the systems were found to be fully or partially functional.
- Unlike hydroelectricity, solar electricity is available throughout the year. Hydropower is not available during the winters.
- Though the overall functionality rates were found to be very high, only 70% of the systems were fully functional. This indicates the backup of support and maintenance facilities for the systems are inadequate. None of the implementing agencies except SWRC has any long-term plans of providing maintenance services or ensuring supply of spare parts like CFLs and batteries. It is hence important to ensure adequate maintenance and repair facilities to all beneficiary households. This is also required since battery replacement will be due very soon for the older systems.

5. Consumer Coordination council

Consumer co ordination council, New Delhi (Mishra Bejoin, 1998) conducted a survey among the users of PV systems in Andhra Pradesh. The results are described below:

95% of the PV customers availed government subsidy to purchase the products of which 83% bought the product through subsidy provided by the nodal agency (NEDCAP) and only 2% through financial institution and 15% direct from the manufacturer.

It was encouraging information that 98% of the PV customers found the product at useful time of purchase and 95% were covered by guarantee/ warranty protection by the manufacturers. 80% customers had no problems with the product information as every product carried booklet but 59% did not have completed product knowledge by using the product.

65 percent product did not receive any training on how to use the product even 91% products carried instructional manuals.

As high as 54% of the PV customers rated the product performance as poor or average and only 2% of the customers rated the product excellent.

As high as 39% of the customers had problems with after-sales service.

Table 9: Features of the product the PV users liked the most

Sufficient illumination	28%
Easy to operate	22%
Saving on electricity bill	17%
Good option for emergency light	12%
Use of solar energy	3%
Low cost on maintenance	2%

The features of the product PV users disliked the most:

Poor battery system.	28%
Inferior quality of tube.	25%
Very expensive product.	18%
Short duration of light.	8%
Restricts mobility.	2%

Major problems with the PV products:

Non existence of after-sales service.	38%
Poor quality of component, e.g. Tube.	31%
Poor quality of battery.	28%
Non availability of spare parts.	17%
Mechanics not available.	2%

FINANCING REQUIREMENTS

The various surveys and the market research indicate that there is a large segment of customers who would like to buy the solar options provided that some instalment options were available. IREDAs World Bank line of credit and the PV Market Transformation Initiative (PVMTI) of the World Bank are bold initiatives in this direction (Murray, 1999. Sinha et al, 1999). The IREDA line of credit is again not applicable to small customer. The presence of subsidy and the time and effort spent to get subsidy also distorts the market. Subsidy through NGOs has been a welcome step in improving the mechanism. Other PV credit studies recommends several measures like the empowerment of NGOs, policy decisions like linking of PV systems with house loans, substitution of subsidies with fiscal incentives, use of carbon trading etc. The availability of micro credits could boost the rural PV market in a significant manner. (TERI-ECN, 1997, Naidu, 1998, Venkatraman, 1998). Here also the networking of local NGOs could be of immense help. The projects like PVMTI, which is based on fiscal benefits rather than subsidy route, are welcome steps.

6. SELCO

SELCO Photovoltaic Electrification (P) Ltd., a SELCO International subsidiary based in Bangalore, Karnataka, was founded in 1995, and was the first company to concentrate on marketing, installing and servicing solar photovoltaic (PV) home systems in rural south India. (Thomas et al, 1998). Its unique feature is that SELCO operates as a profitable business (without dependence on government subsidies) with a firm belief that `solarization' of a rural household is an essential condition for economic development. (Hande, 1996)

SELCO started its ground level activities in the rural villages of Karnataka with a small amount of seed capital from through a US- based non-profit organization Solar Electric Light Fund Inc. (SELF), who have initiated rural electrification projects in several developing countries. SELCO has been the most successful project of SELF so far. Till date, SELCO-India has installed over 4500 solar home systems, besides 300, solar hot water systems and 80 solar water-pumping systems, primarily in the states of Andhra Pradesh, Karnataka and Kerala.

A typical SELCO Branch has its own set of technicians and collection agents in the chosen villages; all hired locally. The technicians work for SELCO on an income-cum-commission basis and are salesmen themselves. Each branch has a branch manager and four technicians. The aim is to provide quick after-sales service to customers while also facilitating monthly collection of loans.

SELCO now has several offices in Karnataka, Kerala and Andhra Pradesh. They have successfully established pioneering, mutually beneficial relationships, with nationalized banks, Grameen banks, NGOs, IREDA and international investing agencies for promoting solar PV systems.

SELCO has set up four marketing mechanisms to suit various customers:

1. DIRECT CASH SALE
   SELCO installs the PV system after a customer places an order with SELCO with advance payment.

2. FINANCE SALE THROUGH NATIONALIZED/GRAMEEN BANK
   SELCO with its yeoman service has managed to convince nationalized banks like Syndicate Bank and rural development banks like Malaprabha Grameen Bank to provide loans for the installation of Solar Home Systems to its customers. Three-to-five-year loans are offered to consumers up to 90% of the solar system cost at an interest rate of 12-12.5%. SELCO takes the total responsibility of performing the following tasks:
   a) Awareness campaigns in rural areas including SPV system demonstration
   b) Identification and pre-qualification of potential beneficiaries
   c) Training of local technicians, installers and service personnel
   d) Installation of solar home systems purchased through the lending bank
   e) Educating users
   f) After-sales service and maintenance.

   This is the first time in India that banks are offering credit for the purchase of SHS and this mechanism has the following specific advantages:
   a) Ready financing is available to the villagers.
   b) Due to the involvement of a local bank, the villagers will have more trust in the solar system.
   c) SELCO does not have the additional burden of collection of loan payments.

3. SELCO -SOCIETY-IREDA SCHEME
   Sale through the Indian Renewable Energy Development Agency (IREDA): In parts of Karnataka where no other type of financing is available SELCO has set up its own financing arm using loans from IREDA. Rural farmers buy systems from SELCO on a lease-to-own basis.

4. SELCO finances SHS to a certain class of customers by providing them loans at low interest rate with IREDA re-financing @ 2.5% p.a. The advantages of this system are as follows:
   a) SELCO has its own financing mechanisms. This gives it the flexibility to create innovative financing schemes according to the prevailing condition in a village.
   b) As surveillance is a local one, loan applications get processed quickly. These village-level operations have given SELCO a solid foundation.

7. SWRC (Social work research council)

Social work research center is a NGO, which started the solar work in isolated regions of Ladakh in 1990. The basic philosophy is to manufacture (assemble) the systems locally and then train local youths for installation, maintenance and other services for the solar systems. This has worked remarkably very well and the systems, even though a bit lower quality, have been functional. The arrangement works for a period of 5/10 years with the sales. (SWRC, 1999)

By 1988 SWRC, Tilonia has had adequate experience in solar Photovoltaic lighting. Tilonia had developed a team of illiterate and semi-literate boys from rural background who could not only do the repairs and maintenance but could fabricate major components of solar lighting units like charge controller and PL lamp Invertor. In 1989, for the first time in the history of Ladakh a small hamlet, consisting of 15 households, Gurgurdo in Kargil, was solar electrified. A semi-literate boy, Karim, who used to work as a porter for supplying provisions to the Army in Batalik Sector, Kargil, was selected by villagers to be trained as solar Barefoot Engineer in Tilonia.

What the plight of these units would be after sometimes it is obvious for anyone to guess. The SWRC gives warranty for smooth functioning of these units for 5/10 year. Remote villages in Ladakh are cut off from the outside world for over 6 months of the year. Poor roads, heavy snow and a non-existing infrastructure in a hostile environment have added to the area becoming virtually inaccessible by the road. There is an air link to Leh located at 3350 meters, one of the highest airfields in the world. The villagers in this region normally live in poorly ventilated houses made of stone and mud, and poplar wood for roofing. They use candles for lighting. One can see small improvised kerosene lamps with a small wick barely lighting the food at mealtimes. In the night people cannot see each other's faces.
In 1989 an alternative was suggested: solar Photovoltaics (SPVs). After an elaborate survey under the Integrated Rural Energy Programme (IREP) for Kargil district it was proposed that individual houses in remote villages will be electrified using SPVs.

The government agreed after great reluctance to try out this solution on an experimental basis. The systems were chosen after hours of discussions with the people - the actual users - depend entirely on the trust in the innate ability the people had for adapting and accepting sophisticated technology for their own needs and not depending, eventually, on anybody outside their village. Accordingly, the following decisions were taken:

1. No electronic engineer or anyone holding a formal professional degree would be involved. Barefoot solar engineers would be trained from the village to do the job.
2. The barefoot solar engineers would be from the village, not from any nearby town or city, because the investment in training should not be lost. They should have roots in the village and want to go back and stay there.
3. The barefoot solar engineers should have the minimum of educational qualifications. If they were semiliterate or even illiterate it did not matter. If it took longer to train them that did not matter either.

The training covered:

- How to install the solar panel on the roof of the house;
- How to carry out the entire wiring of the house and the fixing of the solar tube lights at the agreed location in the house;
- How to fabricate and solder inverters and charge controllers in extremely primitive rural conditions;
- How to carry out repairs and change defective parts in the village itself ; and
- How to in turn become a trainer and a leader in the villages without depending on expertise from outside.

Engineers, knowing fully well that no degree-holder would agree to work in remote villages in the mountains, expected the project to fail. What they did not expect us to do was to go back to ordinary people – the rejected, the unqualified and the socially and the intellectually "inferior" – and appeal to them to take on the challenge. For decades these villages identified by the government were not likely to receive power through DG sets. Even if the transmission lines were erected the chances of getting continuos power for lighting were remote.

The lessons learnt in the last eight years in Ladakh can be summarised:

- People with formal qualifications are not needed for maintenance of solar systems. Any villager, literate or illiterate, can be trained to do the job.

- Any remote village can easily be made self sufficient in solar power, however poor the community may be.
- The community must be involved in the selection of the barefoot solar engineer; in the transportation of the panels to the village and in the installation in their own houses- only then they will pay willingly.
- The rural community must accept only that technology that does not deprive them of jobs and does not decrease dependency.
- The demystification of technology is a process that cannot be rushed. It must move with the pace at which the community moves, slowly, carrying every one along.

A similar project was taken up in Himachal Pradesh by SWRC. The Project Area is situated in Lahaul and Spiti district of the Indian State of Himachal Pradesh. The District Headquarters is in Keylong, which is the main town of the district apart from Udaipur, which is the sub-divisional headquarters of the District. The district has a total population of 31,294 people and is spread in an area of 55,673 sq. Km. It is bound by Ladakh in the state of Jammu & Kashmir to the North, Kulu (in the state of Himachal Pradesh) to the south and Tibet to the East.

Two rural youth were selected jointly by the rural communities of the project Area and SWRC, Team from Tilonia. They were trained as barefoot solar engineers for implementing the project along with SWRC, Team.

8. AIWC (All India women's conference)

All India women's conference is a NGO based in New Delhi who are the nodal agencies for the promotion of solar energy and micro credit in rural areas particularly involving women. (Mishra, 1998)

The committee selected the project on solar lamps for microenterprises as one of the best pilot projects for funding of US $ 2000 (funded by CIDA).
The main features of the project are –
Solar lamps were given on the lease basis to the beneficiary's daily/monthly collection
The project is sustainable as it pays back the investment after five years.
AIWC has successfully launched the programmes on two sites Saharanpur (U.P.) and Jaipur (Rajasthan) by way of creating awareness, technical personnel and providing them systems.

Impact of solar Lamps project to the beneficiaries

- Created awareness among masses about the solar Lantern/thermal systems
- The beneficiaries are feeling proud of that they are using urban consumer durable products. These who got the solar lanterns in their houses taken the device as urban consumer durable and taking care of the system properly.
- Open up the opportunities for rural employment for the technicians (20) trained during the training programme.

Provide employment for 4 persons at Saharanpur regarding implement and collection of beneficiary share.
The corpus funds has began set up with the branch as per the beneficiary collection of per day use and the amount collected is utilized for the repair and maintenance and purchase of more solar lanterns.

The beneficiaries response

- Helped them for doing income generation activities like cutting/tailoring
- Education of children
- Help in doing their household work

- Community response is very good and participatory

Problems
- Collection of beneficiary share, the facilitator has to visit many times to collect the money
- Collection of beneficiary share is difficult due to over flowing of water in river Yamuna
- Regarding ownership of solar lantern – the beneficiaries demand for the ownership of solar lantern.
- Problem of collection in 3 to 5 cases most often as reported by the branch

The project has been able to accumulate the collections and the money is being ploughed back to increase the number of beneficiaries. The results indicate sustainability as apart from the corpus all the expenses have been covered from the leasing revenues.

9. Ramakrishna mission

The Sundarbans is served by the Ramakrishna Mission (RKM), which provides education, agriculture, training and medical services. The RKM is a well-respected humanitarian organisation principally known for their slum-relief activities in the Calcutta area.

The sustainable rural economic development through Ramakrishna Mission Photovoltaic project a Indo-American initiative was conceived as a small-scale demonstration project that would show the economic viability of photovoltaic systems in the sundarbans region of West Bengal. The viability was to be predicted on the systems being economical without any subsidy at all. The operation and maintenance of the systems was to be the responsibility of the RKM. In addition to the 300 home lighting systems, lighting has been installed at youth clubs in Katakhali, Satjila, and Shantigachi. The clinic at Satyanarayan is completed, but the vaccine refrigerator still remain to be delivered by WBREDA.The weaving centre at Pakhiralya is also completed, with the Gosaba Rupayan Lighting system remaining to be installed. (Stone et al.1998, 1999)

One minor problem with the home lighting system has been the flush mounting of the PV modules on the thatched roofs. This hinders air circulation behind the panels, which prevents cooling that would improve the performance. Flush mounting also leaves the panels titled at the pitch of the roof, of about 40 degrees. The slight penalty by not having the panels at an optimum 30 degrees is minor. Because the panels are facing south, they catch the cooling breezes from that direction.

The RKM is very committed to PV for SHS. Since the NREL systems have been installed in the region. Up till now, The RKM has focussed their attention on four districts, South 24 parjanas, Midnapur, Bankura, and Gosaba.

Table 10: Details of the NREL-MNES project:

Systems Summary				
System Type	Quantity of systems required	Number of Solarex VLX-53 Modules per system		Charge Controller, One per system
		(each)	(total)	
Home Lighting	300	1	300	Sun-Saver-6LVD
Training Center	1	5	5	ProStar-30 Marine
Youth Club	1	2	2	“
Weaving Center	1	5	5	“
Clinic	1	5	5	“
Portable Lighting	1	2	2	“
Vaccine Refrigeration	1	10	10	“
Spice Grinding	1	14	14	None
Water Pumping	1	16	16	SA-1500/SP5A-7
Street Lighting	15	1	15	Pump
Solar Lantern Station	1	1	1	Trace C-12
Auto Battery Station	2	88	176	ProStar-30 Marine
				Two APT2-4X special

Homeowners were asked what they used for lighting before PV. The majority used hurricane lamps that use kerosene. Their fuels costs were 60 to 80 Rupees per month. This provided two lamps for 4 hours per night.

The recent reports of the evaluation of the project indicate well functioning of the systems although some component failures have been reported. (Stone et al. 1997,1998, 1999)

Central battery charging stations

Several attempts have been made in the past to setup battery charging stations right from a two module station for lanterns to 500W stations for battery charging. All the earlier attempts fizzled out for unknown reasons. One of the possibilities is that the technology and market perceptions were not conducive to the idea. The recently installed NREL central charging station has started functioning and would be an interesting to watch its performance.

SUMMARY

India has large potential for solar power especially for electrification of a large number of scattered villages. The solar systems are more economical than the grid extensions for villages, which are more than 3 km away from the grid. The Govt. of India has been extending support for solar systems. Earlier attempts to popularize these systems through demonstration and subsidized distribution were failures due to a) inadequate development of the product and b) absence of after sales service. It was realised that after sales service is most important if the solar systems have to be successfully commercialized.

Solar lanterns and solar home systems have found wide acceptance as clean, eco-friendly option for lighting. The successes of NGO based approaches such as SELCO , SWRC, .AIWC and Ramakrishna Mission due to their well-planned repair and maintenance services along with improved availability of reliable products has made the systems user friendly. All the systems backed by local trained technicians have shown flawless performance. There has been a perceptible change in the attitude of users and a positive willingness to acquire solar systems even with full down payment. There is a felt need for simple financing mechanisms to help persons willing to acquire these systems on instalment basis. With reduction in costs of PV, there is bound to be substantial growth in the market.

It is also realised that there is a large potential for the commercialization of several PV products if suitable financing arrangements are made available to individuals and commercial users and the PV manufacturers make appropriate marketing efforts. Here again the involvement of local NGOs is likely to yield results. The basic fact remains that the large manufacturers can not provide the user friendly and low transaction cost based supply cum aftersales service.

At present some 6,75,000 PV systems have been installed in India which contain about 1,18,000 solar home systems and 2,80,000 lanterns. (MNES) report 1999-2000. A bar chart shows distribution of various systems cumulative 50MW of solar PV systems installed so far. The growth rate of solar lanterns and solar home systems has picked up during last few years and is likely to increase further. To accelerate the pace of implementation, NGO have also been allowed to receive subsidy. NGO’s like Ramakrishan Mission Ashram, Narendrapur, West Bengal, the All India Women Conference, New Delhi, the Rajagiri college of social sciences, Kochi, the Social Work and Research Centre (SWRC), Tilonia, and the rural development Centre, Manipur, SELCO, have also been allotted targets.

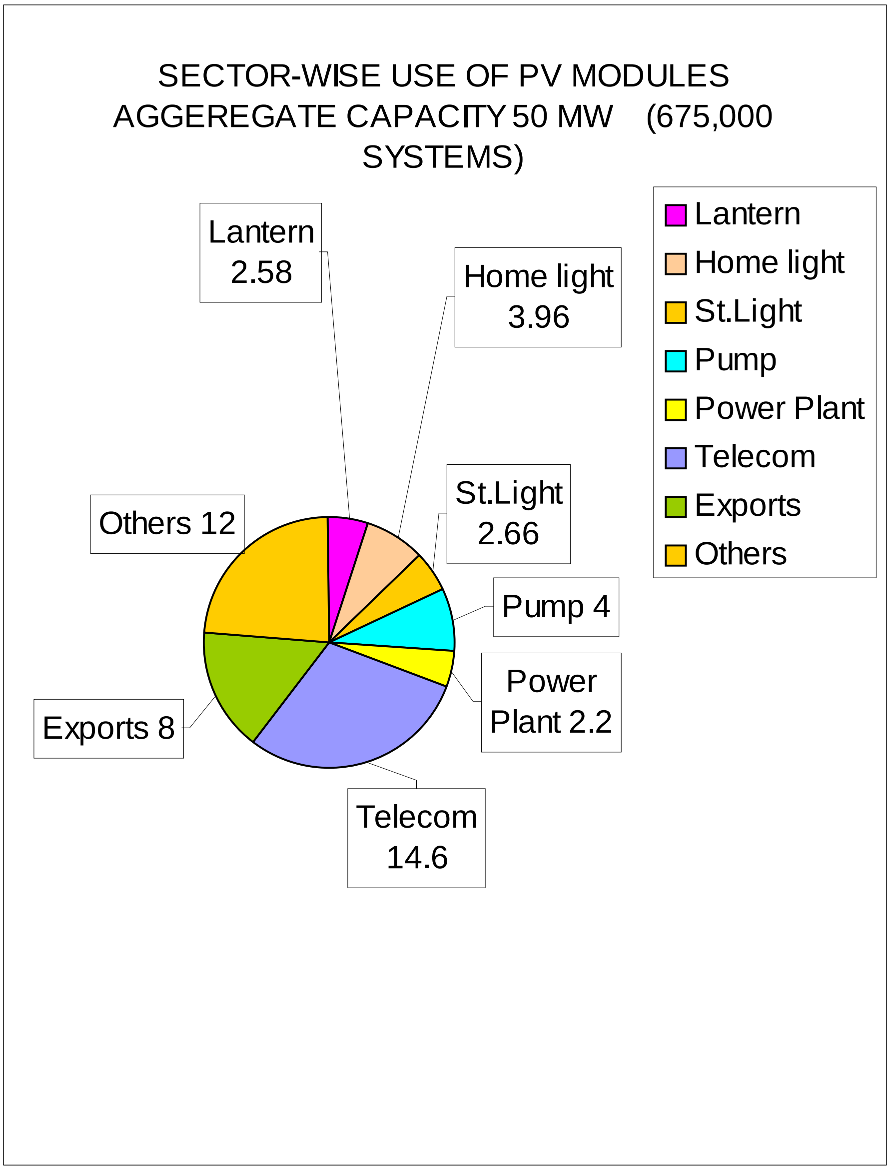
Prospects for the future

There is a growing recognition that PV technology perhaps offers the best prospects for a breakthrough. Therefore the policy of the Indian government is clearly directed towards a greater thrust on all aspects of PV technology and applications. The recent policy measures provide excellent opportunities for increased investment in this sector, technology upgradation, induction of new technologies, market development and export promotion.

Summing major barriers to be addressed in order to create a conducive atmosphere for commercial and consumer sectors to grow are:
- Early poor performance due to ineffective supply chain and inadequate after sales service network.
- Availability of micro credit and its management to expand the customer base that is willing to pay for the services provided by the product.

Both these concerns have been partially addressed so far. Involvement of NGOs and creation of local after sale service centers involving the local youths has improved the transaction costs and functionality of systems. A lot more is required to expand to larger areas.

There are strong indications that solar energy systems will play an increasingly large role in the rural energy sector in India. The demonstration of reliability under field conditions by some technologies, changes in the institutions involved with the renewable energy sector, a shift in emphasis from direct subsidies to fiscal incentives and funds for concessional financing of investments are among the important reason for the confidence. This flexibility and maturity, both in government policy and in industry dynamics, the firming up institutional frameworks suggest strong reasons for optimism about the growth of solar systems in India.



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ANNEX 5. SUMMARY OF PV RURAL ELECTRIFICATION EXPERIENCE IN THE PACIFIC ISLANDS

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Contents

1. Background

The Pacific Island nations provide an extraordinary opportunity to learn about rural electrification by solar energy. The Pacific countries are small, the population mostly rural and the islands remote, making fuel expensive and shipping unreliable. There is little opportunity for industry having large electrical loads and the modest capability of solar PV is adequate to meet the needs of the great majority of applications. Fluctuations in petroleum product prices have had a major effect on the island economies and governments are eager to reduce petroleum dependence since fuel is the largest single import for many of the Pacific countries. As a result of these factors, the Pacific Islands was one of the first regions to attempt real rural electrification through solar photovoltaics. With the rich diversity of cultures and the varied geography of the Pacific Islands creating numerous tiny independent states, many different approaches to the process of PV based rural electrification have been tried with varying degrees of success.

By the early 1980s, solar photovoltaics had been shown to be a reliable, cost effective power source for hundreds of remote telecommunications systems in the Pacific. Also the cost of photovoltaic system components had fallen to levels which made photovoltaic systems competitive with small diesels for domestic lighting and limited rural electrification. Though by 1980, a number of individual homes had been electrified using photovoltaics, the first Pacific Island projects which were specifically intended as models for general rural electrification were initiated in 1981 and 1982 in French Polynesia and Fiji. Since that time, Papua New Guinea, the Cook Islands, Tonga, Kiribati, and Tuvalu have also implemented programs intended to be the basis for photovoltaic based domestic rural electrification.

By 1980, it was clear from their experience with small, diesel systems that Pacific island stand-alone rural electrification has social, administrative and technical problems not faced by urban electricity systems. Further, individual home power solar photovoltaic systems had not been tried for general rural electrification and their maintenance needs, fee collection processes, administrative structures and other support needs had to be determined by trial and error. In addition to these basic institutional problems, the technical experience with photovoltaic systems for home use was very limited and optimum sizing, reliability, battery type and the need for charge or discharge controllers were still not known. Since no successful model for photovoltaic rural electrification had yet been demonstrated, each country approached the problems differently and a variety of project designs resulted.

2. Major Project Concepts Tested For Five Years Or More

Unless severely lacking in proper technical design, photovoltaic systems are unlikely to fail during the first year of operation. Systems with excess capacity and oversized components may function with virtually no attention for three years or more. Therefore, a minimum period of five years of project operation is needed before a project can be properly analyzed and problem areas identified. Most countries of the Pacific have attempted several photovoltaic rural electrification projects prior to 1995 with many dating back to 1985 and earlier. From the experience of those long term projects, a number of lessons have been learned.
Though dozens of different photovoltaic rural electrification projects have been implemented in the Pacific region between 1982 and 2000 totalling several megawatts in total capacity, they all fit one of the following conceptual forms with minor variations.

3. Aid Funded, Government Installed, Community Owned And Maintained Individual Home Systems With Government Technical Support.

1. Concept
This model was the one first used in Fiji in 1982-84. Three village co-operatives were formed, each slightly different in concept but all formed with the intent of local monthly fee collection and self maintenance. A total of about 100 systems consisting of a single 42 Wp panel, a 45 Ah gel-cell battery, a discharge controller with "D" cell Ni-Cd charging capability, and two 12V direct current fluorescent lights were provided under Fiji Government and USAID funding. They were installed by the Fiji Department of Energy (DOE) with the assistance of villagers who were trained in their installation and maintenance. After installation, the DOE was available to the co-operatives for technical assistance and as a source of spare parts. A portable light and four rechargeable Ni-Cd "D" call batteries were also provided each household.

2. Experience
Each village had a different experience with the project, though none were satisfactory. One village never completed all installations and no systems remain functional; one completed the installations but maintenance was not carried out beyond the first few months with no systems remaining functional and the third village managed to keep some systems partially functional though most systems had major component failures which were not repaired.

Most Ni-Cd "D" cell batteries were lost, damaged or destroyed within six months of installation. Most of the portable lights became inoperative within a few months of use. Many Ni-Cd chargers attached to controllers failed due to attempts to charge dry-cell batteries or to general misuse.

Nearly 100% of the fluorescent light fixtures failed within the first year. This was attributed to a design flaw and though these were replaced by the manufacturer without charge, the cost of replacement was high due to the remoteness of the sites which increased the repair technician's time and travel costs.

No panels failed. The gel-cell batteries appeared to be adequate considering the under sizing of the panels in relation to appliance use. Nearly half of the controllers were incorrectly adjusted when received and had to be reset at the Fiji DOE where acceptance tests were undertaken. Following installation, most of the controllers were inoperative after two years and as they were sealed, they could not be repaired.

3. Lessons Learned

Self collection of fees for maintenance was not successful. This approach appears unlikely to be successful because almost any reasonably well designed photovoltaic system will operate for a year without maintenance and local committees soon decide to use accumulated funds intended for photovoltaic repair for other apparently more pressing purposes. When battery replacements do become necessary several years into the project, funds are no longer available for their purchase and either cheap and unsatisfactory automotive batteries are purchased, government assistance is requested or systems are abandoned. In the two villages with completed projects, collections were good at first, soon became sporadic and in the end, though collected fees should have been sufficient for most repairs, virtually all purchases of replacement parts were made by government and most systems were ultimately abandoned.

The initial choice of one panel and two lights was based on the expressed desire of villagers for an average of four hours of light a night. In actuality, villagers appear to average more nearly six hours a night and it is clear that a single panel of less than 75 Wp is insufficient to meet actual needs.

Villagers which were initially trained for maintenance were often changed later in the project but no additional training was provided. As a result, maintenance quality rapidly fell. Even when the trained person remained for a longer period, maintenance quality fell because there was no external authority to assure continued attention to proper maintenance procedures and technician discipline became lax.

4. Government Installed, Government Owned Systems with Basic Maintenance By Owner and Energy Office Technical Assistance On Call

1. Concept

This model has been used in the Cook Islands, PNG, Tonga, Palau, Fiji, Federated States of Micronesia, Vanuatu, and the Marshall Islands. Project sizes range from over 200 installations in Fiji (from 1984-1990) to a few units for technical trial in PNG. All early systems used a single panel between 40 and 50 Wp capacity with later systems generally 75-100 Wp in capacity. Batteries ranged from locally made, relatively inexpensive open cell lead-acid batteries to expensive batteries specially designed for photovoltaic systems. Most had charge/discharge controllers though some of the Fiji systems had no controllers and some other systems had only charge control. All used fluorescent lamps operating off 12V direct current in the range 13 to 18 Watts per fixture. Most installations included two lamps though some in Fiji included three. Capital sources were either the Government budget or external aid. In some projects, user fees were charged with collection of fees by government employees or through local government agents.

2. Experience

Most single panel systems have been abandoned, are operational at reduced capacity or have had unacceptably high maintenance costs due to frequent battery replacements. In no case, have the photovoltaic systems installed under these projects consistently performed as intended by governments or as expected by users for five years or more.

Though basic maintenance was intended to be handled by users, effectively governments provided nearly all maintenance. Users rarely did any effective maintenance and often damaged systems through ignorance or attempts to get more than design power from batteries. Government maintenance was generally sporadic and of widely varying quality with long repair delays common.

Spare parts were often not available and usually could only be obtained through special overseas order making repair delays even longer.

Because many of these projects were implemented in phases, notably those in Fiji and the Marshall Islands, different equipment was installed at different times. This led to confusion regarding spare parts and repair procedures with repaired systems often having different, sometimes poorer, operating characteristics than the original design.

Fee collections were sporadic and generally ceased after a few months. Users were receiving such poor service that they often refused to pay. Government agents collecting fees kept poor records, in one case falsifying them and pocketing several hundred dollars intended for the repair fund. In few cases were fees that were collected actually used for system repairs.

Quick response centralized maintenance was also shown to be uneconomic because of travel time and transport costs. In an attempt to make technician travel to remote rural sites cost effective, it was common for a government technician to visit each project one or two times a year rather than when needed for repairs. In other instances, the technician would not be sent for repairs until enough systems had failed to make it worth the trip. Thus, if a system failed immediately after a visit, it would remain out of service until the next visit many months later. It was also not unusual for the technician to travel to the site, determine what the problems were and then wait until the next regular visit to do the repairs because parts were not immediately available or there was no budget for an immediate return. User frustrations were therefore high and photovoltaic systems were branded as unreliable.

3. Lessons Learned

Systems having a capacity of 50 Wp or less were clearly shown to be inadequate for general home lighting in the rural Pacific.

User maintenance did not work because (a) users rarely *actually* have sufficient experience or training to undertake even simple technical tasks; (b) users often *perceive* their limited knowledge to be sufficient to successfully modify systems and many systems were damaged as a result.

Government maintenance from a central office is not satisfactory due to excessive delays in repairs and high repair costs.

Fee collections need to be timely and cost effective with adequate controls to insure proper accounting. A separate photovoltaic maintenance fund should be established rather than collecting fees into the general treasury then making repairs from the Departmental budget.

Spare parts appropriate to the project need to be immediately available for repairs and need to accompany technicians on repair visits.

5. Donor Supplied Equipment And Installation, Government Contracted Maintenance

1. Concepts

In the period 1982-1994 over 2,000 rural homes of French Polynesia were electrified by photovoltaics with funding predominately from the European Community and the French Government. An engineering, training and testing organization, the South Pacific Institute for

Renewable Energy, and a sales and service organization, GIE Soler, were formed specifically to handle the design, installation and maintenance of this large scale rural electrification project.
Systems installed ranged from early 175 Wp systems to systems of over 800 Wp in later phases though for each phase, all users served received identical systems. The component quality was high and systems were well designed.
Maintenance was provided by technical personnel based in the home office of GIE Soler (now privatized and named Soler Energie) on Tahiti who were required to travel at high cost by air and sea to project sites for maintenance. To fully understand this task, it is important to know that the surface area of the Pacific Ocean covered by French Polynesia is about the size of Europe. Thus having central maintainence in Tahiti is roughly equivalent to having a technician in Paris responsible for maintaining a PV system in Warsaw. Maintenance visits were irregular and had a typical frequency of one visit every three to six months.
No user fees were charged during the early years of the project. Maintenance costs were moderate as the oversized, high quality systems had few problems.

2. Experience
By 1989, batteries of older systems were failing in quantity and maintenance costs had risen to levels which were difficult for the Territorial government to maintain. Therefore a process for fee collection to cover maintenance costs was proposed. Island local governments were contacted and requested to sign contracts to cover maintenance fees for systems on the islands. Few island Mayors in fact agreed to the fee payments and several have opted to shift to highly subsidized diesel based electrification. For nearly three years during this transition, maintenance was minimal for those islands refusing to sign fee payment agreements and the installation of several hundred new systems funded by the European Community was delayed until the problem could be resolved.

3. Lessons Learned
Even providing systems of high technical quality which are fully capitalized by external donors is not sufficient to insure long term project success. While the temptation is great not to charge users for maintenance during the early years of a technically successful project when actual costs are very low, battery failures begin to occur in quantity from five to seven years into the project and costs become so great that it is then very difficult to recover full maintenance costs from users. Massive refurbishment subsidies become necessary if the project is to continue.
For long term institutional and financial viability, fees must be set at the beginning of the project in an amount sufficient to cover operation and maintenance of the project over its full life. Even in the relatively cash rich economy of French Polynesia it has proven nearly impossible to belatedly impose fees on systems originally provided at no cost. Even collecting fees for new systems when there has been a history of providing systems to other users with no fee has proven very difficult.
From a policy point of view, establishing very highly subsidised diesel electrification schemes without equivalent subsidies for PV make it very difficult to convince island governments to continue with PV electrification.

6. User Owned And User Maintained Systems With Commercial Maintenance Available On Call.

1. Concepts
All Pacific countries have some domestic, rural installations of this type. Fiji, Kiribati and PNG appear to have the most with around 400 installations in Fiji, about 300 in Kiribati and probably over 200 in PNG.
Though designs vary, the great majority are single panel, two to three light systems. Since users are paying full commercial price for the systems, the tendency is to purchase minimum systems to keep the price as low as possible. In most countries, private businesses were the supply

source. Rarely did photovoltaic system sales provide more than a small percentage of the business of these firms and most claimed to be operating the photovoltaic part of their business at a loss with an expectation of future improvements. Technicians at these firms rarely had specialist knowledge or experience though most were competent in general electrical repairs. The major exception to this was in Kiribati where the government owned and USAID funded Solar Energy Company was formed in 1984 for the sole purpose of selling photovoltaic systems to rural users and providing technical assistance for their installation and maintenance. Their business was exclusively solar photovoltaics and their two technicians were well trained specialists in solar installation and repair.

Two main classes of Pacific island customers exist in this category: religious institutions and private individuals. Many if not most of the systems privately sold in PNG for domestic rural electrification have been to rural religious missions for house lighting, refrigeration, small scale water pumping and communications. In the other countries, private customers appear to be in the majority though church sponsored institutions remain an important customer group.

Installation may be by the owner or by the seller. Most have been by the owner since the cost of having a commercial technician visit a remote site for installation is a significant percentage of the system cost. Most vendors provided a rudimentary set of installation instructions which generally are useful only to persons already having some level of technical capability. Again, the exception was the Kiribati Solar Energy Company which provided comprehensive, local language instructions for installation and maintenance. No matter what instructions were provided at the time of sale, surveys of installations performed by users in the private category show the installations to rarely be satisfactory with common errors being poor panel orientation and placement, inadequate wire size, poor battery connections, fixtures improperly mounted and connections having unacceptably high electrical resistance.

In Kiribati where good written instructions in the local language were provided with systems as well as verbal instructions at the time of sale, private user installations appear no better than those in other countries with minimal instruction.

Even where vendors provided the installation, it was common for 240V wiring procedures to be followed rather than the more stringent ones needed for 12V and 24V systems. Connections and wire sizes which are perfectly adequate at 240V often cause poor performance at the higher currents and lower voltages found in photovoltaic systems.

Installations at church institutions have been generally higher in quality because commercial installers are hired or because the institution has a "handyman" with sufficient technical experience to follow the instructions provided.

Maintenance quality ranged from excellent to non-existent with most private systems being very poorly maintained and most institutional systems reasonably well maintained. The quality of maintenance varied according to the technical capability of the user/owner, interest in doing the maintenance and financial resources available for purchasing repair parts and services.

Repair calls to the vendor have been rare among private customers due to the high cost of technician time and travel. Institutional customers were more likely to call on the vendor for assistance with particularly difficult problems but usually depended on in-house capabilities for repairs.

Early battery replacements have been common in this class of installation for two reasons: (1) systems are usually undersized in an attempt to get initial costs down; and (2) poorly trained users or institutional "handymen" usually replaced batteries without determining why the battery failed. Excessive shading, incorrect controller settings, improper panel orientation, excessive loads, wires too long or too small, appliance problems and poor connections can all cause real or apparent early battery failure. While replacing the battery appears to repair the system, in fact the new battery may also be doomed to a short life since the other problems persist.

Upon failure of the deep discharge battery generally provided with the original system, both private and institutional owners often used an automotive type of battery as a replacement. Sometimes this was due to the inability of the vendor to provide proper batteries. More often it was simply a matter of cost. These have a life of from six months to three years according to the amount of excess capacity in the system. With the undersized systems usually installed by private users, automotive batteries often have a life of less than one year.

2. Lessons Learned

Vendors need to realize that selling undersized systems without support is seriously undermining the reputation of solar photovoltaics as an acceptable home electrification technology and endangering the future of their own business. Vendors need to establish a good rapport with customers and carefully interview them in order to design systems to meet their real needs. They must provide them with quality instructions in the language of the rural districts (rarely English). In particular a list of "do nots" should be provided. A realistic estimate of the actual capability of the system being sold should be provided. The procedure needed to contact the vendor for replacement parts or technical assistance should be written down for the user. Vendors should retain a detailed list of components sold to each user for reference when replacement parts are needed. Installation instructions in the appropriate language must be provided with replacement parts.

Vendors need to have more after sale contact with customers. When in the area, vendors should visit customers, check installations for errors or maintenance problems and make recommendations for improving the performance of their systems. When sufficient customers are in a particular rural area, it may be financially practical to offer them a reasonably priced technician visit on a regular schedule if enough agree to participate.

The specialist knowledge of most commercial "solar photovoltaic technicians" is limited. Considerably more attention to specialist training is needed particularly in the areas of panel orientation and placement, wiring procedures for low voltage direct current systems, battery selection and installation and controller troubleshooting and adjustment.

7. User Owned And User Maintained Systems With Commercial Maintenance Available On Call.

1. Concepts

In the period 1983-1985, a foreign owned private company claims to have installed nearly 200 lighting systems in Fiji under a leasing arrangement. For a basic lighting system with a single panel and two lights, a monthly fee of F$15 (at the time approximately US$17) was charged. This fee included maintenance when requested by the user.

Local field agents responsible for specific geographical regions were trained in the installation and maintenance of the systems. They also collected fees. A spare parts stock was kept by each agent. According to the business owner, many of the customers were village stores which had been using a small diesel generator for lighting power. For them in particular, F$15 per month for the solar lighting was cost effective.

2. Experience

Field agents were not as reliable in making collection visits as intended and customers were often in arrears using poor system performance as a common excuse. The business failed for several reasons. Prominent on the list of problems was a poor collection rate, several instances of dishonesty on the part of field agents which were costly, with at least one agent making up systems for his friends from the spare parts stock.

The most serious problem was that maintenance costs proved higher than collections due to the under sizing of the systems for the loads imposed and early battery failures were too common.

Company operations were inefficient because the number of systems per field agent was too small. The administrative structure necessary to properly supervise and control the agents could not be justified with the small number of systems in any one geographical area. Also, agents tended to view the photovoltaic tasks as of low priority since they were only part-time and undoubtedly many collections were not made and many repairs were delayed as a result. Because a spare parts stock had to be maintained for each agent, a larger investment in spare parts was necessary than would normally be needed for the total number of installations being serviced.

3. Lessons Learned

Most of the problems encountered were due to systems being dispersed over a wide geographical area. For lease based photovoltaic electrification, it appears to be very important both for control and efficiency to have full time field agent/technicians with no less than fifty systems serviced by each agent. Effectively, this dictates that marketing should be community rather than nationally based with no installations being made in an area capable of being serviced by one man, until at least fifty contracts can be assured.

It appears better to provide isolated single installations as a lease purchase or financed sale arrangement with maintenance a separate contract negotiated for each installation.

Customer complaints about performance, which often lead to collection problems, are usually the result of under sizing of systems or a lack of understanding on the part of the customer as to what can be expected from the system being provided. For small systems, under sizing problems are usually due to skimping on panel size rather than battery capacity. Adding another panel to the one panel system doubles the system capacity but increases the capitalization cost only two to three dollars per month since panel life is 15 years or more. The improved operating conditions which result can dramatically increase the life of the battery and thereby lower the maintenance cost several dollars per month. The result can be a system which is far better from a users point of view with a full cost recovery fee which is unchanged or only slightly higher than that of the one panel system.

User education is a valuable investment since it has been shown to lead to improved customer satisfaction and lowered maintenance costs. It should be a standard part of the leasing process.

8. Commercially Installed And Owned Systems With Commercial Periodic Maintenance, A Pay-As-You-Use Approach - Fiji

1. Concepts

Conceptually, this project approach was intended to overcome a social problem encountered in earlier community based photovoltaic electrification projects which caused collection problems. This problem is the unwelcome change in family financial patterns resulting from the need to accumulate money for a monthly payment for a photovoltaic system instead of buying fuel in small quantities when money is available. The common pattern for a household using kerosene for lighting in rural villages of the Pacific is to go to the store each day or so and buy a bottle of fuel for immediate use. The change to providing these small daily payments to saving for a larger monthly payment appears surprisingly difficult for many households. It was therefore postulated that a photovoltaic lighting system which could be paid for in many small payments instead of one relatively large monthly payment would be better received by the rural populace. While the obvious approach of a coin operated system was considered, they have been tried with conventional water and power systems for rural home supply and have generally failed due to the ease of jamming or fooling the mechanical coin receptacles as well as problems of corrosion in the salt laden and high moisture content air. Collection of the coins from the boxes at each house was also a problem. The patented "key access" system was designed to eliminate the complex mechanical equipment and centralize collections. To use the system, it was necessary for the homeowner to buy a plastic "key" for F$.60 (at the time about US$0.50) from the village store (which made a small profit from each sale). By inserting the key into a receptacle in the box, then turning it until it broke off, power was provided to the house for a 24 hour period. The effective fee of F$18 per month was higher than had been tried in other projects but expectations were that collections would be better due to the apparent low daily cost which, to the user, was obviously about the same as had been paid for kerosene in the past.

The village of Lovoni, Ovolau, in Fiji was the site of the pilot project using the "key access" system. The solar photovoltaic system consisted of a photovoltaic panel and a large Nickel

Cadmium battery enclosed in a locked fiberglass housing. This was mounted on a pole near the user's house in a shade free area. The house was wired for 12V by the supplier and small, high-efficiency fluorescent lights were installed in the house. All components were selected for high quality and long life in order to minimize maintenance. The expensive Nickel Cadmium battery was selected because: (1) a charge/discharge controller would not be necessary; (2) long periods under partial charge conditions were not damaging; and (3) the manufacturer estimated at least ten years of useful life with fifteen to twenty possible and (4) the manufacturer reduced the price for this trial though still more costly than a comparable capacity lead-acid battery.
Local technicians were well trained and became employees of the firm. Installations were professionally made, users were instructed in the use of the systems and village stores stocked with "keys".

2. Experience
The business failed (for reasons not associated with the project) before meaningful results from the pilot project could be obtained. During the several months the project operated normally, customer acceptance seemed high and the financial returns as expected though minor problems with inadequate capacity were reported by some users. Unfortunately, the arrangements which had been made for financing the business collapsed and the business structure followed close behind.
Following the collapse of the business, the systems remained in the village and were modified to allow continuous access by users at no cost. Most of the systems continued to function satisfactorily more than five years after regular maintenance ceased. This demonstrates that the use of high quality components, in particular batteries, can markedly reduce maintenance requirements for home photovoltaic systems.
In 1999, French funding installed 70 SHS on the island of Moala which uses a prepaid card system conceptually similar to the “key access” system though much more complex technically. Unfortunately the project is too new for there to have been meaningful results yet. A third pre paid card collection system is proposed for the home component of a planned GEF/UNDP project to be implemented in Fiji in 2000.

3. Lessons Learned
Doing everything right socially, administratively and technically is of no value if adequate arrangements for business financing, particularly during the early years, are not made. Solar photovoltaic projects are capital intensive and benefits to owners slow in arriving though potentially profitable in the long run.
The "key access" system remains essentially untried but appears to have great potential if systems of adequate capacity and quality are provided. The prepaid card access system will need to be operated for several more years in the difficult Pacific Island conditions before its long term characteristics can be determined.

9. PV Systems Are Government Supplied And Owned With Some Self-Maintenance But Mostly By Government Employees.

1. Concept
The projects in Namara, (Fiji), Ha’apa’i (Tonga) and Puka Puka (Cook Islands) are similar in that they all have attempted to overcome many of the shortcomings of earlier projects principally through the provision of unusually high quality systems which provide better service and reduced maintenance requirements. In particular the Puka Puka project with its nearly 400 Wp panel capacity and large, very expensive industrial battery illustrates this approach. The Fiji systems include about 130 Wp of panel capacity and the Ha’apai’i systems about 100 Wp of panels to provide basic lighting in most customer houses. In an effort to avoid the problems of user modification of the photovoltaic systems, ownership of the systems is not transferred to the user or a community co-operative but is retained by an external governmental authority. The

administrative system remains tied to government energy office supplied technical support and maintenance with some basic maintenance handled by a local technician expected to be supported through funds raised by the local community in the case of Tonga and Fiji or fully supported by government as in the case of the Cook Islands.

2. Experience

The Fiji and Tonga projects were installed in March-July of 1994 under EU funding and remain in service. In both cases, user fees are supposed to be collected by the community but at a level which is insufficient to provide for battery replacement or other hardware maintenance. Collections were initially good but by 1999, the collection rate was estimated to be only about 65% in Tonga and the return from the customers insufficient to provide long term maintenance in that project.

The Puka Puka project in the Cook Islands remains in service and the oversized, high quality systems have worked well and should continue to work with minimal maintenance for several more years. Since no fees are being collected, that cannot be used as a criterion of relative success. It is too early to know the actual life of the batteries and therefore the cost of system maintenance cannot yet be determined. The access to the island is very irregular and service which depends on technicians from Rarotonga equally irregular. The local technicians have been shown to be capable of day to day maintenance and basic repairs but several systems have required more advanced technical support and long delays for such repairs are the norm.

In all three cases, high subsidies for maintenance are necessary and primary technical support is distant and only part-time in nature as members of the staff of the Energy Offices are being used as support technicians. While this model may work for a pilot project, it is unlikely to be practical for general rural electrification due to the high level of subsidy provided for maintenance and the strain on the modest number of technical staff available to the Energy Offices. Both Tonga and Fiji recognize this problem and are considering other organizational arrangements for larger scale electrification by photovoltaics but none have yet to be formally proposed for adoption.

10. The Tuvalu Experience — National Co-operative owned and installed, periodic maintenance and fee collections by the co-operative

1. Concept: The Tuvalu Solar Electric Co-Operative Society

Solar PV systems were first introduced in Tuvalu in 1979 to power the inter-island telecommunications system. In 1984, the Save the Children Federation (USA) began planning a process for implementing solar electrification on outer islands of Tuvalu. The institutional design chosen was based on the recommendations of the Fiji Director of Energy where there had been the only prior experience in the region with a similar project. As a result of this effort, the Tuvalu Solar Electric Co-operative Society (TSECS) was formed in 1984 by the Save the Children Federation (USA) to provide small solar PV lighting kits to outer island households which at the time were illuminated exclusively by kerosene lamps. The TSECS has grown and until 1995 (when donor support ceased) has generally prospered despite major technical flaws with systems provided by international donors. The organisational structure of the TSECS is both community and nationally oriented. Though receiving no government subsidy, the TSECS has access to external resources through the Tuvalu Government which has an agency to provide services to co-operatives. These arrangements were intended to provide the close relationships necessary for customer satisfaction even in the face of technical difficulty while remaining impersonal enough to collect fees and establish disconnect policies that were non-discriminatory.

Phase 1 - Save The Children (USA) Assistance

With the Save the Children Federation (USA) in the role of project co-ordinator, the TSECS was established as a private, commercial enterprise in April 1984 and charged with implementing and managing the household solar lighting project. The TSECS has no direct links with Government though it is regulated by government through the Co-operatives Act and must therefore submit annual reports for auditing. In May, 1984, using funding from the United States Agency for International Development (USAID), TSECS began operations with the purchase of 170 lighting kits. Their design was based on a combination of the recommendations of the Fiji Director of Energy and the Tuvalu Telecom Director. They were intended to provide basic household lighting of not more than 4 hours per night and consisted of the following components:

- 12V 35 Wp 30 cell Arco panel
- 12V modified car type lead acid battery
- 2 - 15 Watt Thinlite fluorescent fixtures.

Inclusion of discharge controllers was proposed by the Fiji Director of Energy but they were not included on the recommendation of the local Telecom Director who believed them to be unreliable and unnecessary. Units were initially installed on each of the eight islands on a pilot basis to familiarise the island community with the technology. Concurrently Save the Children Federation (USA) Island Development Co-ordinators were trained in system installation and maintenance. A TSECS Branch was established on each island when a minimum of 20 households deposited A$50 each with the TSECS and expressed their willingness to pay A$6.25 per month for the use of the household solar system. That financial arrangement was structured to cover maintenance over the lifetime of the system and component replacement costs for any part no longer operating to specifications as a result of normal use or accidental damage. It did not provide for recapitalisation of panels, however. This was consistent with the Government pricing policy for Diesel generated power on Funafuti which also does not cover capital replacement.

The first Island Chapter of TSECS was established in 1984 and by late 1985 all 170 of the original lighting kits were installed. The systems worked poorly and most batteries failed before completing the first year of operation and often within six months of their installation. The primary reasons for early failure were (1) the 30 cell photovoltaic panel was inadequate to properly charge the battery, (2) excessive battery discharge was present in the absence of a discharge controller and (3) use of the lights was greater than anticipated by the system designers. Failure of lights were also common due to an apparent flaw in the electronic ballast design.

In June 1988 after completing it initial objectives, Save the Children Federation (USA) withdrew its administrative support form the TSECS. The co-operative then became an independent, locally owned and operated commercial enterprise. While investment in PV systems has thus far been donor based, just as has been the Funafuti Diesel powered grid system, all TSECS operating expenses have been paid by income from the member fees since 1988.

Phase II: Early EU Assistance

The second phase of the programme began in 1985 and involved the installation of 150 household lighting kits provided by the EU (then EEC) under its Lomé II Pacific Regional Energy Programme (PREP). Those kits were modified from the initial design to include a battery controller to prevent abusive patterns of use. The new systems contained the following components:

- 42 Wp BP model 1235 PV Panel (some had 33 and some 34 cells)
- Fiji-made deep discharge type 12 V 90 Ah lead-acid battery
- Fiji designed and manufactured discharge controller

- D Cell NiCd battery charger
- DC/DC converter (series regulator type)
- 2 Thorn 2-D type 16 Watt fluorescent fixtures modified for 12 V DC operation.

The discharge controller was poorly specified by the donor with no mention in the specifications about internal energy use. The controllers provided were a first time design by a Fiji based electronics firm and their internal, continuous power requirement was over 2.5 Watts. Over a 24 hour period, the energy used by the controller equalled that used daily by one of the lights. As a result the system could not provide the amount of lighting needed.
The lack of a specification requiring a specific number of cells on the panel resulted in panels which were a mix of 33 and 34 cell units though the Wp rating of all panels was as specified. Due to the shifting of the maximum power point with increasing temperature, at the high temperatures encountered by panels in Tuvalu, a 33 cell panel is marginal in its ability to fully charge a 12V lead acid battery when a daily use cycle is encountered.
The lack of an illumination efficiency specification in the tender resulted in the purchase of a light which consumed over 21 Watts of 12V DC power in a 16 Watt fixture. The light supplied was one which had been converted by the Fiji supplier from a 240 VAC fixture to 12V DC operation rather than a unit specifically designed for 12V DC PV applications.
The specifications did not require the supply of components which had a proven record of success in Pacific Islands PV service. As a result, the batteries chosen were of a new design, manufactured in Fiji, which had not been tested through field service in PV systems. Field experience and later laboratory tests showed that the quality control of the batteries was poor with some units performing as intended and others having a cycle life far less than that which was acceptable for PV service.
The inadequate purchasing specifications resulted in the supply of panels, controllers, batteries and lights which were technically inferior and when assembled as a system could not consistently provide more than two hours of lighting per night in Tuvalu. The results were again disappointing and did not meet users expectations.

Phase III - French Assistance
To overcome the component problems and design flaws of the initial PV systems funded by USAID, external grant assistance was secured from the French Government in 1987 to upgrade those systems by their provision of appropriate controllers and batteries. This emergency support kept the USAID systems operating and TSECS from an early failure though it did not solve the problems with the EU provided units.

Phase IV – EU Upgrading Assistance
Following its evaluation of the systems provided by the EU to Tonga and Tuvalu, the Energy Studies Unit of the University of the South Pacific (USP) determined that the design was technically inadequate. This was independently corroborated by the PEDP. As a result, the EU was requested to replace the unsatisfactory controllers and batteries as well as to add a second panel in the systems that they had provided under the 1985 scheme. The EU agreed and the equipment was ordered and provided in stages between 1988 and April 1990 under the Lomé II PV Upgrade Project for Tuvalu and Tonga. In this upgrade, the EU provided 160 Photowatt 36 cell panels including rack mounts and wire, 165 Oldham (France) 100 Ah 12 V deep discharge type batteries, and 175 charge-discharge controllers that were developed by the S.P.I.R.E. specifically for Pacific Island applications and assembled by GIE Soler in Tahiti, French Polynesia.
This upgrading project was completed in December 1991. As a final step to bring all systems up to an acceptable standard, an additional 125 12V 120Ah BP Solar (Australia) batteries of intermediate quality were provided in 1992 through the FSED Small Energy Projects Programme. The purpose of this project was to replace those batteries originally provided in 1984 by USAID as well as many batteries from the French project of 1987 since a number of those batteries were failing by 1992.

The period 1984-1991 was one of constant change due to problems with equipment and organisation. By 1992, the upgraded USAID, French and EU funded systems were providing satisfactory technical performance. Also a renewed emphasis by the TSECS on proper system use, increased institutional support, and improved service by the local technicians resulted in a higher level of customer satisfaction and few problems with equipment failures indicating that the TSECS was an organisation competent to provide PV based rural electrification.
On 1994, the EU provided an additional influx of equipment for upgrading older systems and installing systems for new users. At the completion of this project, over 400 members of the co-operative were electrified by solar photovoltaics. In 1996 a waiting list of nearly 200 households who had requested PV systems remained due to a lack of capital availability.

2. Experience
Technical problems dominated the period prior to 1992. Technical problems beyond the control of the co-operative kept many systems from performing to the full expectations of users and those problems were solved through the PV Follow Up Project of the EU. Users were presently generally satisfied as shown by a high on-time collection rate and a waiting list for new installations.
In the period 1993 to the present, institutional problems have been dominant. The General Manager, who had been in office since the TSECS was separated from the Save the Children organisation in 1988, was found to have systematically embezzled most of the funds of the co-operative and was sentenced to prison for a seven year term. None of the money was recovered. This created a serious financial situation and the TSECS has never completely recovered from the blow.
In 1996, the Management Committee of the co-operative voted to suspend the General Manager which they suspected of misuse of funds despite no actual proof and despite the extraordinary improvement in the administration of the TSECS which he had accomplished, voted to lower the fee for all members to A$5 (well below a level to allow sustainability) and voted to double the technical staff on each island despite the fact that maintenance had been of high quality with the single island technician following the new General Manager's institution of improved training and supervision processes. These actions were reviewed by the Government office responsible for overseeing co-operatives and were not placed into effect due to their clear fiscal irresponsibility. Nonetheless, whether imposed or not, these actions do indicate a common problem with co-operative structures which is a lack of technical and business competence on the part of the managing committees and the fact that the persons voting on fiscal matters directly benefit from actions which are not always best for the long term financial viability of the organisation.
While capital for new installations must presently be obtained from aid sources, the TSECS is the first national rural electrification program in the Pacific region which has been at all self-sustaining in operation and maintenance.

3. Lessons Learned
The administrative and maintenance system used by the TSECS appears to be the key to their initially successful operation. It is important to note that their relative success is not due to technically superior PV systems but to an administratively appropriate and culturally relevant organisation. Indeed, the technical quality of the aid provided PV lighting systems in Tuvalu was so poor prior to 1990 as to be an embarrassment to the donor organisations. Also, other countries in the region have received identical USAID and EU PV systems for rural electrification of communities very similar to those in Tuvalu but have had their projects almost immediately fail while the same technical systems continued to work and provided basic lighting in Tuvalu.
The main points of the TSECS approach to PV rural electrification which are different from other concepts tried previously in the independent Pacific nations are: (1) monthly visits are supposed to be made to every user by full time, specialist trained, locally based employees of the organisation who not only collect fees but check on the operation of the systems and perform regular minor, but essential maintenance; (2) senior technicians visit every site at least

twice a year to check on the quality of the local technician's work and to solve problems beyond the local technician's capability; (3) fee collections are by an impartial organisation based outside the community and fees are used exclusively for the benefit of the project; (4) users have a local path to management through their Branch Committee members when conflicts arise with users and agents, particularly regarding disconnects and the collection of fees for poorly functioning systems; (5) users, through their committee representatives, are kept informed about how fees are being spent, what improvements in service are being proposed, and can, in turn, register direct complaints about service and management methods or expenditures they feel are inappropriate; (6) the entire national organisation is devoted just to providing rural electrification services by PV power; and (7) more than one size of system is available to meet varying electrical needs and financial resources of users.
The co-operative concept unfortunately has serious problems due to poor oversight of management, policy making committees which have little technical or business experience and a tendency to set fees too low preventing full cost recovery because fees are set by the persons paying the fees. Financial accountability is weak and planning tends to be poor. All of these problems have been endemic in the TSECS and the present situation is one of institutional deterioration and poor service as a result. The Tuvalu Government has recognized the problem and several proposals for reorganization of the TSECS into a rural electrification utility structure like that of the SEC in Kiribati have been made though to date no changes have been implemented.

11. The Kiribati Experience. Five years of direct system sales with maintenance on demand at commercial cost followed by 10 years of corporate owned and installed systems with periodic maintenance and fee collections by the corporation

1. Concept
Kiribati utilised PV for some small communication purposes and a few private lighting and pumping systems were present in the country in the late 1970s and early 80s. However, the first national involvement with PV for general rural electrification began in 1984 with the formation of the Solar Energy Company of Kiribati (SEC).
The SEC was established as a private enterprise by the Foundation for the Peoples of the South Pacific (FSP), a U.S. based NGO which has offices and projects in many of the Pacific nations. The SEC was established using USAID funding and was organised as a private corporation The initial private shareholders were FSP and the Bank of Kiribati with shares also held by the Ministry of Works and Energy.
Its original charter was to act as a retail outlet for solar PV systems and to provide technical assistance where needed for their installation and maintenance. The company was not, however, organised to provide services other than on demand by customers and there was no regular maintenance process implemented for systems that had been sold.

2. The SEC, 1984-1989
With technical assistance from the UN Pacific Energy Development Programme (PEDP) and the South Pacific Institute for Renewable Energy (S.P.I.R.E.), the SEC developed a competent technical staff and a stock of components suitable for Kiribati including PV panels, batteries, high efficiency lights and charge regulators. These items were available for sale individually or as a system. Installation manuals and maintenance manuals were prepared in the local language and were provided with items sold. The staff was available to customers for free consultation in the office. For site visits, a charge was made which covered the labour, travel and subsistence of the technician.
Analysis of other solar village electrification projects indicated a number of significant barriers to sustainable PV rural electrification. Each of those problems were addressed in the design of the SEC sales and service effort. They were:

Harsh environmental conditions
There had been a high percentage of failures of batteries, lights and controllers in Pacific installations due to the harsh environmental conditions in the islands and to inadequate designs.
The Pacific Island environment, and in particular the atoll island environment, includes continuous exposure to high ambient temperatures, high humidity and to an atmosphere with high salt content due to the close proximity to the sea. Additionally, in Kiribati the rural homes are of traditional construction with thatched roofs and walls are non-existent or consist only of thin wood strips or woven screens. These buildings provide little protection from the environment and electronic and mechanical components in these homes commonly suffer from rapid corrosion as well as insect and dirt damage. To minimise this problem, the components selected for sale by the SEC were specifically ones which had a proven record of reliability in the Pacific Island environment. Further, a booklet, written in the local language, was provided to customers to help them choose the proper components and to adequately size their systems.

Poor quality installations
Improper orientation of panels, inadequate ventilation of panels, excessively long wires, wire that is too small, high voltage drop connections, low quality switches and the use of automotive type batteries all were common problems in the early Pacific Island installations which led to early failure or unreliable performance. The SEC provided well illustrated, local language instructions for the proper installation of their components and detailed information about proper maintenance. Verbal instruction was also provided at the time of sale.

A lack of trained personnel to provide maintenance and repair services
Earlier PV rural electrification projects in the Pacific Islands included minimal training for a local, part-time technician. Training was usually provided by the company supplying the equipment and was rarely of high enough quality to allow the “technicians” to handle more than the most basic, routine maintenance. No further training was available and should the trained individual leave the village, adequate training for a replacement was not available.
The SEC staff included two full time employees who received high quality training specifically in PV system installation and maintenance at international courses organised by PEDP and S.P.I.R.E. They were available to customers for consultation at no charge and the SEC provided on site service for the cost of their travel, subsistence and labour.

Inadequate stock of replacement parts
Prior Pacific Island solar projects were hampered in the long term due to the lack of in-country replacements for failed components. This caused long delays in the obtaining of replacement components or resulted in the replacement of the original high quality components with lower quality, more readily available units. In particular, this was found to be a problem with batteries where replacements were almost always low quality automotive type batteries instead of the appropriate deep-discharge units originally provided. As a stocking distributor of solar components, the SEC maintained a full line of high quality replacement parts and delivery could be provided off the shelf for panels, charge regulators, lights and batteries. All were items specifically selected for reliable operation in PV systems on Pacific Islands.

High initial investment for a PV system
The initial investment in materials for a PV system ranged from about US$500 for a minimal solar lighting system to about US$1500 for a system capable of powering four lights for six or more hours per day as well as powering small entertainment appliances.
To minimise the cost to its customers, the SEC purchased in bulk quantities using competitive pricing. Approximately 50% of the SEC’s inventory was paid for by USAID in two separate grants. To avoid distorting the market, the components were sold at full price and the grant support was used to offset the staffing and administration costs of the SEC which resulted in lower than market cost technical support. For selected customers with known credit or who demonstrated a long term financial capability, credit sales were made and financing through a

number of smaller payments was provided. The lack of organised rural financial services in Kiribati prevented the general credit financing of systems.

During the period 1984-1989, about 270 PV lighting systems were sold to private customers throughout rural Kiribati. Additional sales of larger systems were made to schools and government agencies.

In 1986, the FSP relinquished all its shares in the SEC to the Ministry of Works and Energy (MWE), making the MWE the 99% owner of the corporation with the Bank of Kiribati retaining the remaining 1% ownership. Since then, the Board of Directors has been selected by the Minister of Works and Energy and has consistently been a mix of influential persons working in both public and private enterprise. The corporate charter was not changed and the SEC continued to operate as a private, commercial sales organisation with no financial support from the government.

Despite the USAID grants and a rational approach to the private sale and support of PV RE systems, by 1989 the SEC was effectively bankrupt. Annual sales had dwindled to the point where even salaries could not be covered let alone providing money for reinvestment in inventory.

In an attempt to determine the reasons for the dwindling sales and to provide data on how to proceed with further PV implementation, the SEC requested the Forum Secretariat Energy Division (FSED) to fund a country wide survey of rural PV system purchasers.

3. The Outer Island PV Survey

Purpose and Goals

The purpose of this 1992 survey, funded by the FSED Small Energy Projects Programme and carried out by the SEC, was designed to determine the number, quality and history of existing solar PV installations in Kiribati. The results were to be used to establish policy for the provision of systems to outer islands, to establish an acceptable method for consistent, affordable maintenance, to determine what was needed in spare part stores and to support existing users in improving their systems through advice, service and supply of components.

In particular, the cost and practicality of establishing outer island technical support was investigated and a determination was made of the best organisational structure to provide the badly needed maintenance support.

Procedures

All villages of all islands in the Gilbert Group (18 atolls) were visited for the survey representing over 90% of the rural Kiribati population and almost 100% of the private PV installations. The team made a particular effort to locate all PV systems to insure that as many as possible were examined and the owners interviewed. This included even those systems which were out of service. The presence of a solar panel constituted a reason for an interview.

Survey Results

Of the 270 PV systems found in the Gilbert Islands, less than 10% were more than marginally operational. The major problems found were:

1) *Improper Design and Installation.* Virtually 100% of the systems had not been maintained other than to replace components which failed. Battery life was found to have been much shorter than should be the case and components had not been kept free of dirt and insect damage.

50% of the systems had been installed without a charge or discharge controller, a requirement for satisfactory battery life with these small systems.

48% of the installations had serious wiring deficiencies, usually in the form of twisted connections or wires that were too long for their size.

43% of the systems had replaced the original deep discharge batteries with automobile batteries having inadequate capacity and a short life expectancy.

27% of the systems used PV modules having 30 cells. In the high temperature environment of Kiribati, at least 33 cells are needed to adequately charge a 12V battery supplying power on a daily use cycle with 36 cells preferred.

16% were oriented so poorly as to provide insufficient output for battery charging.
13% had panels placed in locations where excessive shade was present.
Many system owners had replaced the original high efficiency fluorescent lights with automobile head lights or tail lights when the fluorescent bulbs failed. Others added CB radios and other appliances. Both actions resulted in a daily energy demand which was greater than the capability of the panels and batteries to reliably provide.
Since the average age of the systems surveyed was less than three years, the concept of providing for PV based rural electrification through dependence on the private marketplace was determined not to be a sustainable and appropriate concept for the conditions in Kiribati.
Specific reasons for this failure were found to be:
2) *Cost.* Even with financing spread over several years, the cost of systems to the typical rural household is high and there is a strong tendency to undersize the systems to save money. Also, the tendency is to not install a controller due to cost. If the systems were properly sized, not installing a controller would not seriously lower the reliability of the system but when combined with undersizing, this invariably results in the life of the battery being dramatically shortened.
3) *Lack of Technical Skills.* The skills of the typical rural householder do not include those needed for a semi-technical installation such as for a solar electric system. As a result, the quality of the installations was poor even though instructional materials were provided. Though professional installation was available from the SEC essentially at cost, that cost was more than the purchasers of systems were willing to spend.
4) *Lack of Maintenance.* Preventive, routine maintenance has been shown to be essential to the reliable operation of PV systems. Battery life with systems which have received basic, externally provided, monthly preventive maintenance has been consistently more than double that of systems maintained by owners. Owners of PV systems did not recognise the value of preventive maintenance and deferred any maintenance until the system was no longer functioning adequately. By that time, irreversible damage to the battery had usually occurred and its life had been drastically shortened.
5) *Use of Unsatisfactory Replacement Components.* The cost of the high quality, energy efficient appliances and system components suited for small solar system use is relatively high. When the original components fail, particularly the battery or lights, the lowest cost conventional replacement is often made. In the case of the lights, this usually more than doubles the effective energy load on the system and greatly shortens the battery life. In the case of the battery, battery life is also drastically shortened because of the mismatch of automotive battery design to the requirements of solar lighting systems.
6) *Low System Density.* The systems are spread thinly over all islands since distribution is controlled by the market, not by the supplier. Since it is not cost effective for the sales company to maintain a local technical staff unless at least 50 households are willing to utilise contractual maintenance services, in the initial stages of the development of the PV market it is not cost effective to place company technical support on each island. With the cost of transport high and the delays in obtaining transport significant, the cost of maintenance visits was higher than most users were willing to pay.
The end result was unreliable systems, a high rate of expensive battery failures and general customer dissatisfaction. This translated into general distrust of PV as an electrical supply source and reduced sales to the point where the sales company could not stay in business.
The survey pointed up the fact that due to the market driven distribution of systems, the number of systems on any single island was not sufficient to support a local technician. Though many of the system owners expressed a strong interest in obtaining a maintenance service contract in the A$5 per month range, the cost of service provision from Tarawa would be too great.

4. Kiribati Rural Electricity Utility Concept

In 1989 when the SEC faced bankruptcy and it was clear that the private market oriented approach to PV rural electrification was not a success in Kiribati, assistance was sought from S.P.I.R.E. to advise the government and the Board of Directors of the SEC as to what should be

done. The result was a recommendation to convert the SEC from a sales oriented organisation to a service organisation based around a rural electricity utility concept.
The recommendations were:

1) Systems would be owned and maintained by the utility. Appliances and house wiring after the battery connection would be owned and maintained by the homeowner.

This is consistent with general electrification practice where the utility owns all generation and distribution up to the power panel in the house. This specifically was included to avoid the problem of householders modifying the primary system components. This was intended to insure that the battery, controller and panels would be selected correctly and installed properly and that appropriate replacements would be installed should failures occur.

2) Rural electrification districts would be set up under the utility. Each district would be of a sufficient size to be properly serviced by a single SEC employee who would be designated as a field technician. This means that no installations would be made until at least fifty households agreed to accept service. A single technician can properly maintain about 125 systems and this would be the maximum size of a district. If more than 125 systems were installed in a district, it would be split making two districts on that island.

This component of the structure was added specifically to insure that a sufficient customer base was present on an island prior to installation in order to make it economically feasible to have a permanent local technician on the island.

3) Users would be required to sign a contract in which they agree to pay an installation fee of $50 and after installation not to tamper with any of the utility owned equipment, to maintain the panel area free of shade, to pay the levied fee monthly and to use the system in accordance with published guidelines — which includes not attaching any appliances to the system without prior approval of the utility. In return, the utility would keep the electrical supply in satisfactory repair, replacing all failed parts at no added cost except for the user owned lights and appliances.

This clause was inserted to help insure that users have the financial capability to pay and could be disconnected if they did not pay the fees or use the systems as intended. It was also intended to avoid the common problem of users connecting high demand appliances or running wires to neighbouring houses thereby exceeding the capacity of the system and causing unreliable service and early battery failure.

4) Monthly fees would be set based on the actual cost of operation and maintenance which is the sum of the costs of battery replacement after an estimated life span of 4-7 years (according to the type of battery and its service requirements), the cost of replacing the controller at the end of its useful life and the operating cost of the utility organisation. Fees would be different for different types and sizes of installations ranging from about A$10 for basic lighting to over A$50 per month for a full system with capacity to operate a refrigerator and video as well as lights.

The intent was to fully recover the operation and maintenance (O&M) cost of each installation from the user. Initial capital investment may or may not be recovered according to government installation subsidy policy.

5) A utility employee who acts as the field technician (and lives in or near the district) would visit each installation once a month to check the equipment and to collect the fee.

The function of the monthly visit was both to perform necessary preventive maintenance and to insure that the user had not made unauthorised modifications to the system which could reduce its reliability or decrease battery life.

6) Twice a year, a senior technician from the Tarawa (home) office would visit each district and audit the field technician's performance. Additionally, a senior technician would be available on call to assist field technicians in troubleshooting and repairs which are beyond the level of the field technician's training and experience.

In order to train field technicians locally, the level of training cannot usually be sufficient to qualify the trainee to provide more than basic preventive maintenance services. More complex problems, in particular determining the causes of battery failure, requires more experienced, better educated and more highly trained personnel. These relatively highly paid senior technicians would be based at the SEC office but would visit each outer island at least twice a year with additional visits to assist the field technician with particularly difficult problems.

7) Each rural electrification district was proposed to have a user's committee consisting of five to seven users elected by the rest of the users in that district. It would be the responsibility of that committee to carry complaints and requests from users to the utility management and to communicate utility matters (mainly reasons for fee and service changes) to the users. The committee would also arbitrate in the case of proposed disconnects due to customer failure to pay fees. It was recommended that if fees are not paid by the users after the agreed upon time, and a disconnect is not allowed by the committee, an additional, temporary, charge should be added to the district bill to pay the delinquent party's arrears amount.

This clause was included to provide for close communication between the SEC and its customers and to allow local arbitration of disconnects in order to retain the community flavour of the project but to require the community as a whole to bear the financial burden resulting from their decision to not-disconnect a user who fails to pay the fee.

8) Annually, the utility would have a general meeting with representatives from all user districts and would publish its fee system for the next year and provide justification for that structure. The user representatives could also air their problems and complaints for utility management response. Simultaneously with the annual meeting would be a week long training workshop for all field technicians to introduce new equipment and concepts and to provide a refresher course for general PV maintenance.

Quality communication with the communities served was considered essential to avoid misunderstandings about fee structures, maintenance policies and opportunities for service modification. Additionally, the meetings would provide an opportunity for upgrading and refreshing training of the field technicians.

These recommendations of the consultant were accepted by the Board of Directors of the SEC and a new management team was selected in late 1989 to implement the PV based utility concept for the SEC. This institutional structure is that which was used to implement both the JICA Pilot Project and the Lomé II PV Follow-Up Project.

5. Experience

Since the completion of the JICA project, which included 55 solar home systems and one community hall lighting system, an additional 250 home systems were provided by the EU and were installed on three islands. Since the completion of those installations in early 1995, the SEC has been successful in both maintaining the systems and collecting the fees. In order to insure that the collected fees are used for the proper purposes, two separate accounts, one for replacement parts and one for operation of the SEC, have been established. The replacement part account can only be used for the purchase of components for the replacement of failed units in existing systems and represents about half the collected fees. The operational account is unrestricted in its use. The collected funds are divided approximately in half for deposit in the two accounts.

At the time of writing, the SEC has been structured as a solar utility ten years with solid field experience for seven years. It is reasonable to consider the approach a successful method of providing reliable village electrification through solar PV in the Pacific Islands. In 1998, an EU evaluation team visited Kiribati, surveyed the electrified islands and examined SEC records and determined that the SEC has indeed been successful in providing reliable service with no recurring subsidy and recommended further support for extending the area of electrification. In early 2000, confirmation of EU support was provided with plans for a project to add approximately 1,400 more homes to the SEC utility structure beginning in late 2000. In April 2000, a JICA evaluation team also visited the site of their pilot project and found the systems to be well maintained and operational and are expected to recommend further support from Japan.

6. Lessons Learned

Clearly, in the Pacific Islands the model used by Kiribati has resulted in the best service to the recipients of the solar systems. The fees have been set for full recovery of operating and maintenance costs and thus far, collections have been high and adequate. Customer satisfaction is high and the quality of installation and maintenance the best in the Pacific. In Kiribati at least, the corporate solar utility model has resulted in a professional approach to solar electrification which seems to have the necessary flexibility, resources and structure to result in truly sustainable PV rural electrification with minimal technical support from the outside other than for training.

12 Conclusions

1. General
Though the first generation of photovoltaic rural electrification projects implemented in the Pacific have not been generally a long term success, an analysis of the many failures and the relative successes in Tuvalu and Kiribati provide several important lessons in both technical and institutional design.

2. Technical Lessons Learned
a. Reliability is the first consideration in component selection.
In the Pacific Island context where transport is infrequent and expensive, reliability of components is very important. Expensive batteries which last five years are a generally better choice than cheap batteries costing one-fifth as much but lasting only one year due to the high cost of delivery and installation when users are in remote areas. Cheap light fixtures are a particularly poor choice since repair and replacement of one cheap fixture will cost much more in technician time and shipping cost than the cost difference between the cheapest and the best fixtures available. Bulb life is also an important consideration. Cheap direct current fluorescent fixtures often require replacement bulbs within 500 hours of operation while good quality units may provide a bulb life of over 10,000 hours.

b. Adding panels to small lighting systems not only improves system performance it improves, sometimes even doubles, battery life and may result in lower system life-cycle costs despite the higher initial investment.
The life cycle cost of batteries is considerably higher than panels. Even the best batteries have a short life if they are operated for long periods without ever coming to a full charge condition. Most early battery failures can be traced to poor charging conditions which can be remedied by increased panel capacity.

c. Discharge controllers are more important than charge controllers for small lighting systems using open cell batteries.
Batteries used with small home lighting systems are usually oversized but panels are usually undersized. Excess discharge conditions are therefore more common and more damaging than excess charge conditions unless "maintenance-free" type batteries are used in which charge controllers are also essential for satisfactory battery life.

d. Panels with less than 33 cells do not adequately charge lead-acid batteries in tropical climates.
The lower voltages provided by panels at high temperatures keep "self-regulating" panels from properly charging batteries in the tropics. 34-36 cell panels are recommended. More than 36 cells appears to provide no improvement in battery charging and the added cost is not justified.

e. Poor orientation and location of panels are the most common installation mistakes.
Of more than a thousand sites visited in Pacific Island photovoltaic rural electrification projects over the past 15 years, more than 25% have panels oriented improperly for the sun’s position or are not shade free from 9 am to 3 pm. System components are invariably selected assuming optimal orientation and minimal shade so variations are always detrimental to performance and play a major role in shortening battery life.

f. Using 240V AC wiring methods for 12V PV systems is a common mistake
Connections and wire sizes which are perfectly adequate for 240 volt alternating current systems may introduce unacceptable losses in 12V systems. Different standards must be used for photovoltaic systems than mains connected systems.

g. Early battery failure is a symptom of other problems.
Though most photovoltaic system failures are evidenced by a failed battery and its replacement apparently fixes the system, if an early battery failure occurs a complete system check should be made to insure that other problems do not exist. Almost every problem with any part of a photovoltaic systems can result in shortened battery life. This is the main reason regular preventive maintenance is important.

3. Institutional Lessons Learned
a. User maintenance rarely works.
User maintenance has been partially successful in missions and church schools but almost never with individual rural users. Users attempting maintenance tasks beyond their level of knowledge often do more harm to systems than good. Battery replacement is usually the response by users to system problems but other problems often have caused the failures. Many problems are subtle and require training and experience to determine.

b. Fee connection and management should be from outside the immediate community.
When fees are collected by a local community organization, collection discipline is lax and funds are often used for other community projects instead of being set aside for photovoltaic repairs. Almost any photovoltaic lighting system using quality components will work without attention for one to two years. In the early stages, it therefore appears that the systems will not cost nearly as much as predicted and therefore the fees being collected are far too large and should be reduced or eliminated. This means that when actual battery failures begin to occur, there are insufficient funds available to make proper replacements and either cheap automobile batteries are purchased or systems remain out of service.

c. Frequent visits by trained maintenance personnel is very important.
Extending the life of the battery is the primary goal of maintenance since it is the single most expensive component over the life of the system. Many small problems can, over time, cause accumulated damage in a battery shortening its life significantly. Frequent, preferably monthly, maintenance checks help insure that battery electrolyte levels have not fallen below minimums, that shading has not become a problem, that connections are clean and tight and that the user has not added more lights or otherwise modified the system in a detrimental manner. The Tuvalu and Kiribati experience indicates that the monthly visit of a technical agent is also important to the users in that it helps them make the best use of their systems through on-the-spot counseling about use problems, reduces system abuse and dramatically improves customer satisfaction because complaints can be lodged in a timely fashion to someone who can often do something on the spot about the problem.

d. Spare parts stocks must be readily available in the field.
While this represents a substantial investment as well as increased inventory control problems, weeks or months of delay between needing a spare part and receiving it from overseas suppliers or the central office stores is unacceptable.

e. There needs to be an arrangement for community based arbitration between any external service supplier and the user.
Disconnects, new customer selection, fee disputes, shade problems involving more than one party and many other minor but often very disruptive problems can destroy a good relationship between the electricity supplier and the community as a whole if a mutually agreed upon means for arbitration is not available.

f. Field technicians should have ready access to technical assistance and should have access to a continuing training program.

Most field technicians will need technical assistance for system modifications and unusual repair problems. Regular visits by senior technicians to provide on-the-job training and to check the technician's work for problems areas is important both to the field technician and to the success of the project. Giving a local resident a one or two week crash course in photovoltaic maintenance is clearly not adequate nor is a system where the technician is expected to call for help only when he is already in deep trouble. Continuing, close communications and regular visits by senior personnel are necessary.

ANNEX 6. LATIN IMPRESSIONS: ARGENTINA

Introduction: Sources of information and knowledge
In Argentina gaining information is much more difficult than in, for example, Brazil, as it seems that there are no central institutions or government agencies involved in following, monitoring or analysing the developments of the PV sector in the country. In fact, until now, the Provinces have led the process of rural electrification, following their task as the main providers or subsidies for rural electrification.
This structure has lead to a situation in which general information on SHS in Argentina is difficult to obtain, especially when visits are restricted to the federal capital, Buenos Aires. Given the fact that the present project did not allow for field visits, this should be considered as a major handicap when analysing the SHS situation in Argentina.
The main sources of information for this country analysis have been a number of personal interviews. Special thanks go to Aldo Frabris, Julio Cesar Llaneza and Walter von Lederbur.

Analysis of the ongoing efforts to introduce SHS in Argentina, by institution

- Between the *Provinces*, there has been a clear difference in approach: Some have decided to consider rural electrification as their responsibility, and have, over the years, installed PV in schools. More recently, they have also been venturing into the installation of SHS. Others have played a more passive role, inviting utility companies to bid on servicing concessions for the non-commercial rural markets. Unfortunately, information on these projects is not available at the federal level, as they consider the development of rural electrification the responsibility of the Provinces.
- In 1996 (?), the *Federal Government* started with a rural electrification program that is based on the use of renewable resources. The program is based on the following principles (see Fabris, A., Argentina, 1998):
  - Market for rural electrification is divided in two parts: A market that is commercially attractive and accessible for conventional (grid) electrification, and a market that is dispersed and economically less developed, and thus commercially less attractive.
  - The Provincial Government gives both markets in concession to a private company. The concession is valid for 45-90 years. Within the concession, contracts for electrification are defined, which are valid for 10-15 years. Within these contracts, the extent of the electrification and the subsidies by the Government are defined. The concessionaire is free to define the type of systems that will be installed, as well as the way it plans to obtain user contributions.
  - The payment capacity of the users is estimated at 10-15US$ a month.
  - Both the Federal and the Provincial Government subsidise the concessionaire, based on the terms defined in the contract. The Federal subsidy is channelled through the Provincial Government.
  - It is estimated that these subsidies amount to about 60% of the total costs of the rural electrification in each Province. This implies that about 40% of all costs of the installation, operation and maintenance of SHS is considered commercially sustainable at this moment.
  - This systems has –until now- only been successful in one Province, Jujuy. However, it should be noted that in this Province, the users paid only US$ 4 per month; the rest of the tariff receiving and additional subsidy by the Provincial Government.
- The concessionaire system has recently gained the interest of the *World Bank and the GEF*. Recently, (10/99) these organisations signed an agreement with the Federal Government to support the extension of the Federal Program. The agreement includes a loan of 30 million US$ by the World Bank, and a donation of 10 million US$ by GEF.

The overall plan is to continue the initiative as it is. The only major difference is that the markets given in concession will not be separated anymore; the new approach is that one company has to service the commercially sustainable market and the non-sustainable market in the region. This change in approach has been possible because:

- The interest of private companies is growing, and they are willing to take the risk. They are interested in developing knowledge on SHS, and consider their participation as a good marketing tool. Also, they estimate that the development of the Clean Development Mechanism will work in their advantage.
- The knowledge on the SHS/ PV market is growing by the day, and it is no longer necessary to consider it as a separate field of action. It is time to integrate PV and other renewables into the standard rural electrification practices.

Although the program allows for the use of all renewables, it is estimated that PV will be the main source for electrification. The expectation is that 80,000 systems will be installed in Argentina under the program.

- In one state (Neuquen?) a *private company* now sets out to install SHS based on a system of pre-payment.
  The prepaid cards are based on the time the user consumes electricity from the solar system (in fact, it does not matter how much is consumed). The cards also allow for flexibility; during high income periods (harvest time) the user can acquire more cards, and thus assure access to electricity during economically more difficult periods.

- Apart from the Government initiatives, there have been several initiatives on an *NGO* and local level. Information on these initiatives is not available on a Federal level and further action is needed if more information is to be obtained.

Other interesting aspects of the Argentinean PV/ SHS sector

- Within the country, there has been no tradition of community development/ co-operatives. Therefore, it seems to be extremely difficult to develop the same mechanisms as in Mexico, Bolivia or Peru. As in Brazil, the only effective approaches might well be the ones in which private companies take the initiative.
- It should be noted, however, that this approach demands a strong Government. In Argentina, since the beginning of the nineties, the Government created ‘Entes Reguladores’ (supervising organisms), that monitor and control all privatised markets. This allows for an immediate correction of activities of private companies in case they do not live up to the contracts included in their concessions. In this sense, the private-lead approach might be more difficult to carry out in Brazil, as it lacks such a well developed supervising institutional structure.
- In Jujuy, demand experience shows that small systems (in Argentina, this means 100Wp) are sufficient to satisfy initial user demand. However, it has been observed that demand grows extremely fast once users have access to electricity. In this sense, Argentina differs from other countries, probably due to the fact that the income per capita is relatively high compared to the per capita income in other rural areas in Latin America. The Mexican experience, for example, shows that demand does not grow significantly after the (subsidised) introduction of SHS in rural areas.

ANNEX 7. LATIN IMPRESSIONS: BRAZIL

Introduction: Sources of information and knowledge

The following information and brief analysis have been compiled on the basis of articles and other types of written sources, electronic conversations with specialists in the field (both from research institutions as from utilities and NGOs) and personal conversations with a number of people in Brazil.

As written information is relatively difficult to find, and rarely reflect the current state of knowledge, the personal input by a number of experts has greatly contributed to this brief summary, and to parts of the analysis presented in the main body of the present report. In Brasil, we especially would like to thank Miguel Morales (USP), Claudio Ribeiro (CEPEL), Fabio Rossa (Ideaas) and prof. Roberto Zilles (USP).

It should be stressed that the analysis in the present summary are based on the interviews, but only reflect the ideas of the project team, and not of the before mentioned experts.

Analysis of ongoing efforts to introduce SHS in Brazil

In Brazil, centralised and state level institutions, have been developing ideas and implementing programs for the introduction of SHS in remote rural areas and other non electrified areas in the country. Amongst these institutions are the utilities in several states, such as CESP (Sao Paolo), CEMIG (Minas Gerais), COPEL (Parana) and COELPE (Pernambuco), and a federal program, PRODEEM, that has been aiming at installing PV to support social development in rural areas.

Despite these large scale efforts to introduce SHS in the country, it seems that the right approach for the introduction of domestic systems as an alternative for grid electrification has not yet been found.

Analysing the problems with all previously mentioned top-down efforts it seems very difficult to assure the operationalisation of the following tasks:

- *Scaling and installation of appropriate systems (size and composition).* Under auspices of CESP, systems installed in the Valle do Ribeira were technically flawed (see Zilles 1999).
  Despite the fact that the formal evaluation of the PRODEEM federal program has not been published yet, it is expected that one of the results of this evaluation is that systems installed in the framework of the program are plagued by design failures. Systems acquired by the program do not meet the demand and physical possibilities of the areas in which they have to be installed and the purely technical design has been poor. Due to this design failures, training of the users seem to have had very little effect. Frequently, users seem to have been transforming the community systems, in order to better meet the conditions in which they ought to be used.
  It is rather surprising to notice that these flaws in design are still occurring, given the fact that internationally recognised solar companies tend to be the main responsible for design and installation.
- Although the *financing of SHS* is most often an intrinsic part of project design in Brasil, in practice, it is very difficult to identify a scheme that has been fully operational and functional for a significant period of time. Surprisingly, in all projects in which the –privatised- utilities play a major role, no tariffs are being collected, despite the fact that the systems are operational (see Zilles 2000).
  It should be noted that in the case of initiatives initiated by NGOs or Municipalities, this panorama might be somewhat different (see SBCS by FTV), but very little is known about their experiences. In case of the Valente project in Bahia (about 350 systems installed and operating), it seems that a strong community sense engenders a sound and sustainable financing structure, but it has not been possible to obtain any sound information on this project.

In case of PRODEEM, the program donates all the systems, and apparently no financing schemes have been put into place.

- *Institutionally*, early SHS programs (e.g. the CEPEL/ NREL initiative in the North Eastern regions of Brazil, in close co-operation with the state utilities) have suffered a lot from the privatisation process the utilities went through.
  During privatisation, the focus has shifted away from SHS, which are still perceived to be a commercially non-viable enterprise. One of the probable causes of the traditional lack of interest for PV/ SHS is most probably caused by the fact that the Brazilian electricity sector is dominated by large scale, grid-related projects, aimed at the urban and industrial centres of the country. As most of the energy in Brazil is generated through hydropower plants, the need for the development of alternative renewable resources is not felt by most decision-makers. An important additional fact is that the rural sector for which SHS are deemed to be a sustainable (pre-)electrification option, is politically and economically marginal.
- A major problem signalled by research organisations and NGOs, is the lack of independent and systematic monitoring and evaluation. Although the CEPEL/NREL project was based on monitoring activities by the utilities, these activities were not sustained after the first year of the initiative; during the privatisation process the utilities lost all interest in the project, and did no longer meet prior agreements with NREL/ CEPEL.
  Nowadays, independent monitoring and evaluation only takes place when the utilities or the federal program allow for it. Alternatively, utilities carry out their own monitoring and evaluation activities. Neither of the two activities guarantee the availability of publicly accessible results. The results presented to a wider audience could thus be biased. Independent checks of presented results indicate that this indeed might be the case.

Brazil vis a vis other countries in the region
Brazil seems to differ significantly from other Latin American countries, in the sense that people seem to be less inclined to co-operate in community structures. This can greatly hamper efforts to develop user associations or community-based credit schemes, and demands a major effort to stimulate the direct involvement of users. In fact, in all these cases, the need for electricity should be accepted as the main cause for inter-personal co-operation.

Positive development in Brazilian SHS sector
At this point in time, a series of SHS projects is starting; the initiatives by CEMIG, PRODEEM and Winrock International in the Amazon region, are mentioned as the most important ones in terms of scale and approach. These projects seem to built on previous discussions and experiences, and set out to overcome the major errors made in the past.
Two of the major utilities in the country –CEMIG and COPEL- have accepted the fact that solar still has to be subsidised, just as all other forms of rural electrification are currently subsidised in the country. Based on their conclusions and field experiences, they are treating solar exactly as they have other energy sources in rural areas.
Also, a number of bottom-up activities, initiated by Municipalities, NGOs or the inhabitants proper, are beginning to emerge. Examples are Winrock, the reaction of the users of the CESP SHS in Valle do Ribeira, and initiatives by NAPER in Pernambuco. It should be noted that on the first and last project only very general information is available, and that all projects are in an initial stage. It is therefore difficult to analyse their results in the framework of the present project. (see Zilles Glasgow 2000).

Word of caution
Despite the optimistic view towards the potential of the Brazilian SHS market, a word of caution is frequently uttered: currently, public opinion is turning against PV, as a direct result of badly managed programs and utility projects. Main example is the CESP-project in Valle do Ribeira, where the proper users are starting juridical procedures against the utility for delivering bad services. Possible, PRODEEM also will have a negative impact on the development of the market and willingness to accept PV.

ANNEX 8. LATIN IMPRESSIONS: MEXICO

Introduction: Sources of information and knowledge
Although the Mexican activities in the field of the application of photovoltaics, and SHS in particular, are extremely significant, there is very little known on these activities. Easily accessible information on the Government rural electrification activities through SHS is extremely scarce. There are several reasons for this:

- Information is commercially valuable, and therefore not accessible to all;
- The gathering and analysis of information (monitoring and evaluation) is expensive and demands a great amount of time. Neither the financing, nor the time is available abundantly. The time and money available is directed at the expansion of rural electrification;
- Politically, the information is extremely sensitive. In Mexico, political influences can be very great, and can make or break an initiative. The anti-PV lobby in the country is known to use negative information to take action against PV rural electrification.

This has been one of the main reasons to visit the country, and try to speak to some of the leading persons in the field. The main resource person for the following summary is Jorge Huacuz, head of the department of non-conventional energy resources of the Institute for Electricity Investigation (IIE) of Temixco, and Carlos Flores, managing director of Sinergia/ Condumex, the national representative of Siemens, and currently the major provider of SHS. Also, special thanks goes to Ricardo Saldaña, as he made it possible to meet with these key resource persons.

Large scale implementation of a PV as part of an overall Governmental Program
Despite the lack of easily accessible, written sources of information on the results of past and present monitoring and evaluation activities, the following information helps to gain insight into the Mexican SHS efforts and results.

- As stated above; the Mexican initiatives related to SHS are extremely significant. Estimations of the number of systems installed through the Government activities range from 50,000 (IIE) to 100,000 (Condumex). Apart from these systems, about 25,000 solar PV systems are sold through the regular, commercial market. The largest number of systems was installed during the 92-94 period, 3 years after rural electrification through SHS took off.
- It should be noted that in Mexico, there is no Government Program that focuses exclusively on rural electrification; all activities in this field form part of the Federal initiatives to alleviate poverty in the country. The names of these initiatives tend to change, but their basic characteristics are constant:
  - A major amount of money is made available to states, departments, municipalities and communities.
  - These have to decide what they want to use it for (i.e. health, education, energy, etc.).
  - If they decide to use part of the funds for energy/ electricity, their demands are channelled through to the Comisión Federal de Energía (CFE). Within this commission, PV has gained interest at the end of the nineties, and is now the main source of energy for poverty alleviation.
- Within these activities two phases can be detected; one of the former government (88-94), and one under the current government (94-00). The major difference between these two phases is the shift in the role of different stakeholders. In particular, during the second phase the municipalities have become the main decision-maker in the development/ installation of SHS. In the first period, the development of SHS was mainly lead by centralised institutions

(i.e. IIE and CFE). The CFE used its widely spread network of regional and local representatives. During both phases, the systems are subsidised by the Government.
Procedures during the first phase: Municipality/community submits a demand for electricity at the Secretary of Social Development, who channels the petition to the CFE. The network of CFE buys systems, and distributes them following the demands made. The selection of communities depends, a.o. on their need for subsidies, and their political role in a region.
In the meantime, in calls for tenders, the offers are received of various companies in the country for a large number of systems (rough estimation is that between 500 and 1000 were tendered within the same bid).
The tenders demanded an offer for the systems, the installation of systems and the post-services. IIIE had developed a quality protocol that describes the minimum standards of the systems. These are not legally binding, but are 'specifications' or 'guidelines'. In practice, during the first phase, no offer that did not follow these specifications was accepted.
The installation of the systems was monitored by the local specialist of the CFE or any other person that functions as an intermediary between the Government and the community that receives the SHS (NGOs, indigenous people's institutions, civil groups that have an interest in poverty evaluation, etc.). Generally, if the systems are not satisfactorily installed, they were to be improved by the installer.
Training was dealt with by the IIE, who started by training the personal of the CFE, and later technicians in the field. Also, information was given to the people receiving the systems, either by IIE or by CFE.
Maintenance was and remains the responsibility of the users.
During the second phase, the municipalities obtained higher decision making powers, and are considered the main decision unit. They choose the type of systems that they want to obtain and on the type of service they expect from the dealers delivering and installing the systems. Also, the Municipality selects the dealer that will in the end sell them the systems.
This implies a number of changes compared to the first phase: The large-scale tenders disappeared, and the distribution network has to become small scale, and locally oriented. Also, the role of the professionals of CFE diminished. In stead of being the main local co-ordinators of the installation of systems, they are now more like a technical expert, that can or cannot be consulted by the municipalities. The role of IIE also diminished; even if systems do not respond to their specifications, they can be sold and installed. It is to be expected that the choice of dealers and systems will be more influenced by other than purely technical interests than before. Likewise, some 'wrong' choices are likely to be made due to a lack of knowledge by the municipal decision-maker.
The power shift also has had implications for the effectiveness of the training program; instead of training local technicians it has become more important to train representatives of the municipalities.

- Currently, there is an evaluation going on of the entire Government activities. A large number of systems have been analysed, and results are expected any time. It is too early to come up with any conclusions, but it is clear that the implementation of SHS has both positive and negative aspects:
  - Not all systems are working as they were intended. There might be technical defects, but these are not the main cause of the malfunctioning of part of the systems. The main cause of less than optimal performance seems to be bad maintenance. Also, the replacement of components is a problem. Another problem mentioned is the sales of systems.
  - Positive developments are that there is still a significant interest for PV in the field, and that new providers have been presenting themselves, thus creating a market structure on a local level that did not exist before. Also, municipalities are frequently recurring to the local CTE representative or the IIE for more information and technical assistance.
  - It is noted that indigenous communities –often the poorest part of the rural population-take best care of the systems. The communities that have lost their traditional practices

and institutional structures have far less interest in maintaining the systems and become self-sufficient.

Other interesting aspects of the Mexican experience

- Demand of systems and panels is not rising rapidly. The expectations of the main providers (Siemens and Solarex) was that, after the initial installation of systems, people would rapidly want more power, and start buying new panels to extend the existing systems (mainly 50Wp, some smaller, some bigger). There are probably a number of reasons for the relatively insignificant increases in demand, two if which might be:
  - People lack the purchasing power to buy additional panels and the complementary machines;
  - People have no interest in additional electricity, as their lifestyle does not demand it. In fact, studies have demonstrated that people who have access to conventional electricity from the grid tend to have a constant demand, which is limited to light, radio and – sometimes- TV.
  - A further hypothesis is that the activities of the Government might be discouraging the development of a commercial market for SHS. The fact that people expect to ‘receive’ a highly subsidised system by the Government causes them to wait until the systems are indeed installed through this mechanism. They do not consider buying the systems as a valid alternative.
- The activities are sustainable as long as the Government maintains its interest in rural development/ poverty alleviation. This might change with the coming government, which might very well be more inclined towards the free market principles and a less paternalistic role of the Government.
- The activities of rural development, including electrification, have to have a strong local content, as Mexico is the country with the highest number of indigenous people in Latin America (relatively, Guatemala might have a bigger indigenous population, but Mexico has the highest number of people and ‘tribes’). Each group has its own customs and rules, which must be respected if SHS-electrification is to work. Therefore, not only technicians/ engineers develop projects, but teams include sociologists/ anthropologists.
- The role of the USA in the PV market has been rather strange; they clearly have an interest in the market, but do not seem to be able to gain access to it. In fact, since the beginning of the nineties the Department of Energy (DoE) of the USA has been sponsoring a renewable energy program in Mexico, in which NREL, Winrock and Sandia are the major players. However, they have not been able to install a significant amount of SHS. Although Sandia frequently claims that it has been playing a significant part in PV in Mexico, it has only installed water-pumping systems, and its role is very limited.

  The American push for the Mexican PV market might stimulate the World Bank to make an offer for a loan to the Mexican Government, to further support the PV rural electrification. The World Bank approach –demanding that the distribution will be made more dependent on financing by the user- might be more acceptable to a future Mexican Government, which will probably tend to move away from the paternalistic approach followed until now.
- However, it is not likely that the subsidies will disappear, as this will be politically unsustainable. People have grown accustomed to a Government that actively provides this type of services, and will not accept a sudden and total change in attitude. Also, a significant number of people will otherwise not be able to obtain SHS. Thus, the challenge is to make the rural electrification activities more efficient, without disrespecting the socio-political context of rural Mexico.

ANNEX 9. IMPACT ASSESSMENT OF PHOTOVOLTAIC TECHNOLOGY IN THE CENTRAL AMERICA REGION

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The government role in rural electrification

There is Governmental concern to encourage the rural electrification efforts to bring electricity to the furthest places of the country. This concern has oriented the governments of the region to prepare a series of steps to facilitate the investment in the electric subsector and to play a solidarity and subsidiary role. In this way, they can fulfill their obligation as defined by the National Constitution, to assure that rural electrification develops in an equitable manner. Examples of such efforts are the electric law in Guatemala, incentives for renewable energy law in Honduras, creation of National Commissions of Energy in the region, and so forth.

Finding niche markets for photovoltaic energy

Institutional inertia in the region to support the rural electrification to hook communities to the Interconnected National Systems, has always dominated the institutional expectative and the creativity for investments. However, lately it is possible to observe that there is concern about the geographical area and niches in which difficult degrees to make conventional electrification are enormous. Definitions of such niches let the renewable resources of energy be more competitive and preferable.

When characterizing the energy consumption pattern in the rural population, it is important to emphasize that those families show a low actual and potential requirement of energy (around 7 kWh per month) for basic needs which are: lighting and entertainment (radio /BW TV). Studies done by NRECA in the region, established average current expenditures of US$ 5-8 per month for lighting. Traditional sources commonly used in the region for rural lighting are: kerosene (used in home-made kerosene container) or by using candles, pine torch or simple 1.5 V batteries. However, based on the rural communities income, there are families with higher energy consumption and a higher capacity and willingness to pay. These higher capacities to pay are based on their economic status in those rural communities, which make them an attractive niche that guides natural interventions from a market eager to attend those needs. Those communities, that are looking for opportunities, generate a social and institutional pressure on governmental entities and cooperation organizations. This has been an important sign for an active government involvement and international cooperation entities to look for resources and creative mechanism to attend this dispersed target - population, poor, low consumption and without general opportunities in non electrified villages.

The key role of intermediaries and communities in electrification by PV

Photovoltaic technologies are performing a key role to attend those niches that are unattractive for rural electrification with grid extension. The institutional concern and community involvement are becoming crucial in the sustained growth of the rural market that can be covered by photovoltaic systems, specially in Guatemala, Honduras and Nicaragua. Considering the capacity to pay, international support and governmental involvement we would estimate a potential market of approximately 200,000 families in Guatemala, Nicaragua and Honduras for the next 10 years in areas without possibilities to be connected to the grid (Dirección General de Energía, Plan Indicativo 1999).

Guatemala

An important characteristic in the Guatemalan situation is the presence of a diverse institutional group promoting and financing photovoltaic projects. Some governmental entities (Fondo Nacional para la Paz – FONAPAZ, Fondo para el Desarrollo Indigena Guatemalteco – FODIGUA, Fondo de Inversión Social – FIS and Ministry of Energy and Mines – MEM), Embassies (Swiss, Japan, Netherlands), international NGO's (CARE, PLAN INTERNACIONAL, UNDP, etc.) and local organizations that are promoting the technology and working jointly with the communities on rural electrification programs and community centers using photovoltaic systems. There are about 12 local suppliers of integrated packages and components. Siemens, Kyocera, Solarex, Isofoton and Golden Genesis are the main international trade marks for hardware in the country.

A basic kit (hardware and installation) costs approximately between US$ 480 - 560 depending on the installed capacity and quality of the components, the quantity of kits requested and the geographic location of projects. Two credit programs have been established for community projects: CREDIEEGSA (actually not available for PV) and NRECA-BANRURAL (available for PV). Other programs were established for PV projects in Genesis Empresarial and FUNDAP, but they are currently suspended because communities want are demanding to be connected to the grid and paid by the trust fund. Such funds from the credit programs are used to complete the financial scheme for the projects, where are also participating funds from the international cooperation and from the governmental entities. The annual interest rate in credit programs in the NGO's normally is about 30% in local currency and the approval procedure also requests collateral (normally the equipment itself is committed), income evaluation and debt history. The amount of the loan normally is to complement other funds.

The Ministry of Energy and Mines (MEM) has developed an important leadership providing funds for implementation projects using photovoltaic systems. Considering the group of national and international entities involved in the PV dissemination, it is estimated that an amount of approximately 2,800 systems has been installed at national level. About 350 of these systems are installed in community centers such as schools, health clinics and churches. MEM has kept the leadership in investing in SHS. At the moment, they are defining a new role as a facilitator. They look for alliances to leverage their scarce funds and to encourage the participation of local NGOs to maintain the leadership in coordination and to implement large-scale SHS projects as demanded by the large non electrified area.

The lack of institutionalized support mechanisms in the post-project stage of the photovoltaic projects has been one of the main hindrances to make photovoltaic technology accepted and purchased by the people. Support is needed to follow the communities and to identify weaknesses in the process of transference and learning. However, investors, support programs and governmental agencies do not provide enough funds to finance the post-projects stages (evaluation, training, productive uses and so on). This lack of vision made that projects were abandoned. Considering the relatively large amount of SHS that has been installed, just a few isolated and not systematic evaluations of photovoltaic projects were made. The most effort was done by the Minister of Energy and Mines, Solar Foundation and NRECA, with active participation in projects such as: San Buena Ventura Project (build by NRECA-Sandia and evaluated by Fundacion Solar-Universidad del Valle), Projects in Lanquin and Chiquimula (build and evaluated by MEM), School Lighting Project (build and evaluated by NRECA).

MEM has just finished a rapid appraisal of their projects that include about 1200 photovoltaic systems[5]. They have considered practical issues, technical performance and basic problems under real conditions of use. A similar approach is being developed by NRECA to perform a continuous improvement plan for the institutional methodology. Solar Foundation / Winrock International Group is implementing two initiatives for monitoring system performance. The first initiative, Metrics, is sponsored by Sandia National Laboratories and will review the performance and failures in about 350 PV systems. The idea is to investigate component failure, system integration and community acceptance. In the second initiative, as part of the Post-Mitch program, CARE in Alta Verapaz will define indicators for designing and monitoring PV projects. The first results of the evaluation of the PV projects in Guatemala show the need for a systematic follow-up to identify weaknesses in the stability of the project caused by an inappropriate transfer of technology to the end user. It has also been learnt to strengthen the organizational and managerial capabilities, to establish of a seed fund for regulatory and other non-technical issues that may have strong effects on the sustainability. Field visits, interactive research in their local languages and practices focused on weaknesses are becoming common ingredients for a more effective practice. A common mistake at the beginning was to define the men as the target for the training. Later, the emphasis was changed to women and children who normally spend more time in house, while the men go out to work in coffee, sugar and urban opportunities depending of the season.

The results of the rapid appraisal show that the technology has an appropriate performance according to the needs. However, the above-mentioned problem of communication, lack of follow up and the cultural identity create specific problems in each specific site that affect the transfer process of technological, social and managerial knowledge to the communities. As an example, good projects (for example in El Jute, Huité, Zacapa, Guatemala) failed when the local organizational structured is weak and lack of trust in the local leaders do not stimulate the families to deposit their monthly payments for replacement of system components.

The entities involved in PV technology promotion suggest that there exists a common filling: lack of sound, deep and statistically verified information from field evaluations of PV projects. Such data will help to understand what is really happening with our assumptions about “end users’ needs and the hardware”. It remains to be investigated whether the assumptions, about the expected performance of the components to fulfill their needs are appropriate, whether the time of use per load is correct, and the technical losses, safety measures and security level as considered in the design are as expected or the weather effect on the autonomy level is cost effective. In addition, it will help to evaluate the need of certification of the components and installations and specially to monitor the impact of the teaching-learning process in target groups and decide if modifications have to be done to the methods for dialogue and approach of the targets groups. These efforts will improve the expected sustainable benefits from the technology, when it is adopted and adapted to the living conditions of the end user.

The Director of Energy of the Ministry of Energy and Mines announced the creation of a National Coordination of Rural Electrification that will take care of the quality standard in the hardware and the procedures used by the project implementers. Governmental agencies will participate in this coordination unit and will follow the proceedings.

It was reported (by the entities involved in PV Projects) that the lack of an entity and of funds for appropriate technical assistance, project preparation and evaluation have created misunderstanding and confusion in the end users. Communities do not know where to go to present their studies when they look for financial assistance. ANER (National Association of

[5] A formal document is being prepared about the learned lessons in the projects and target area.

Non Electrified Communities) was organized to support the organization of community committees and to guide them in presenting their pre-investment studies prepared by NRECA. This mechanism is just emerging and is not institutionalized by other actors.

The coming months promise an appropriate availability of funds for photovoltaic projects. While the central government is providing its full support and funds to increase the conventional rural electrification trust fund (with US$ 334 millions to provide electricity to 283,000 families), the group of international entities committed with rural developed in coordination with National Rural Electric Cooperative Association (NRECA) have proposed a joint strategy to work on a joint complementary rural electrification plan. This effort has incorporated the results of the pre-evaluations done, especially a strong support scheme in the post-installation stage to create a full community involvement and to define responsibilities on initial investment and about the mechanism to administrate, operate and maintain the systems.

NRECA's allies for using such strategy in the PV communities are: Minister of Energy and Mines (with scarce funds availability), Switzerland Embassy, Japanese Embassy, USDA-Electricity for Progress Program (confirmed with an available fund approximately $1.3 millions for rural electrification. An important part of the fund, according to the demand, is available to be used for PV projects), USAID-NRECA and its Post-Mitch Program (with about UD$1.5 millions to invest directly in clean energy in the region), the Swiss Embassy – NRECA - MEM and its solar fund (propose a mixed credit of US$ 4.8 millions for photovoltaic projects).

Great intents for extensive rural electrification with photovoltaic panels have failed, such as the one by Total Energy. This plan considered to implement PV in Guatemala, Nicaragua and Costa Rica using a pre-paid mechanism for an integrated service under the Community Service Utility concept. However, in this plan the market and regulatory setting is not clearly defined. Lack of policies to support these efforts and lack of definition of concession area to be electrified using PV could be the main barriers that affect the extensive efforts to promote PV. A better scenario could be defined by the actual trust fund available for grid connected rural electrification program that have funds only for 283,000 families in 2660 villages[6], leaving out about 500,000 additional families.

Guatemala is taking the leadership in the use of PV panels because its advanced privatization scenario is defining who will be part of communities to be connected and who not. A group of NGO's and the international cooperation is doing intensive labor looking for a mechanism to encourage investments in the communities out of the governmental rural electrification plan using the trust fund. The rest of central America is coming behind Guatemala, learning the lessons of the privatization process in Guatemala. Guatemala's government canceled the rural electrification tasks budgeted in the wide range of involved entities, concentrating the governmental effort in above mentioned trust fund that will finance only grid extension. Entities affected by that decision was FONAPAZ, FODIGUA, FIS, MEM and Local Development Councils – Executive Secretariat of the Presidency.

Honduras and Nicaragua will follow with the privatization of electric distribution service and that definition will also clarify the trend for the coming efforts in rural electrification.

Honduras

In Honduras there were not much investment in Rural Electrification, specially considering that rural electrification didn't have a specific responsible to manage the problem. Traditionally, ENEE is responsible for the grid extension programs, but it has no funds or a systematic program for rural electrification. According to technicians of ENEE, they were not in the past

[6] Plan Indicativo. MEM, 1999

nor will be in the future interested to use photovoltaic technology for rural electrification. Some governmental efforts have been done to promote investments in rural electrification, such as FOSODER, the seven cities initiative, the western rural electrification plan with KFW's funds. None of the initiatives have put together the funds to go ahead with the projects, specially addressed to extend the grids and to strengthen the transformation and distribution system. Under such circumstances, with ENEE as leader in rural electrification in the main government, there was no chance for rural electrification with photovoltaic technology.

The CARES Program (Central American Rural Electrification Support) encouraged ENEE's decisions makers and policy makers to consider rural electrification and the productive uses to facilitate rural development. Again, lack of funds and programs in ENEE created spaces for NGOs interested in rural communities, by creating small funds and affordable mechanism to implement PV systems in isolated villages. This led to the ENERSOL Program, that later changed to ADESOL Program, and to AHDEJUMUR (Honduran Association for Rural Youth and Women Development), which started credit programs for solar panels.

The central Government created SERNA (Secretary of Energy, Natural Resources and Environment), which brought big changes to encourage renewable energy projects in the country. SERNA came to integrate the efforts from the NGOs and the international cooperation and also to guide the governmental effort to promote clean energy. The legal framework delegated to SERNA the responsibility for the leadership in energy, including rural electrification policies. SERNA will have to go beyond the formal frame delegated, being creative to look for appropriate alliances to create financial mechanisms to encourage the private sector to invest in clean energy and to leverage the community efforts to attend renewable energy projects.

Actually three formal suppliers are attending the local demand and have developed alliances with other sub suppliers at departmental standard.

There is also the presence of international cooperation entities (FAO, UNESCO, USAID, GEF-PNUD), with pilot projects to promoting their approach to the local governments and institutions to encourage the market of photovoltaic technology. Complementary, SERNA is creating the structure, the alliances and looking for international cooperation to promote clean energy. According to the actual coverage by the grid, there are a lot of zones where PV panels are the only chance to bring electricity to the villagers. Intense efforts are done by SERNA and the Congress to encourage alliances among the National Government and international community.

Regarding to the system evaluations in the country, lack of access to the information from the responsible entities made difficult to know their experiences. SOLUZ, ADESOL and AHDEJUMUR have been promoting their financial scheme as a key factor for technology dissemination. However, problems with their strategies, lack of funds and follow-up are the cause for the low growing rate in their programs. The causes of this low growing rate are not clear; the responsible entities did not respond to our questions.

It is very important to study the strengths and weaknesses of the Honduran cases to analyze the low increase in the technology dissemination and to establish a relationship between acceptance and sustainability and community participation. Honduras has been a case with slow technology adoption rate where foreign entitities managed the leadership in the technology. Lately, people with appropriate background in rural electrification and renewable resources management are making decisions in SERNA, that could change the scenario for the photovoltaic technology.

Also lately, the European Community, UNDP-GEF, USAID and others entities are strengthening alliances with local and regional entities to implement projects in compliance with the Clean Development Mechanism, where PV projects are a key part.

Nicaragua

Efforts in Nicaragua have been made to improve the living standards in the rural area through local initiatives or pilot projects. The Fenix Group, for example, is taking the leadership in rural electrification by using solar panels manufactured locally using disposable cells from foreign industries as raw material. The homemade solar panels do not offer the same level of efficiency as the ones manufactured and certified under international standards. However, they are accepted by the end users and Fenix is becoming a low cost and affordable solution to the isolated communities without expectance for connection to the national system. They have been promoting their solution through the region with less penetration in the market. Also, the Fenix Group offers training for trainers and for leaders in their regions. This disseminate the technology through community leaders and have community activities such as the Solar Sundays Project. One Sunday per 2 weeks, they do demonstration and interactive roles with the villagers.

Parallel to this some efforts and initiatives from local NGOs and governmental projects support PV projects. GEF - UNDP supports Health Clinics; CESEADE, which is supported by a Dutch group of Churches in Nicaragua, considers the PV option for supporting rural villages. ACODEP (local financing group) has developed a credit program that is available to support rural electrification community initiatives and micro-enterprises (Information was requested, but not obtained yet).

We have identified two big photovoltaic equipment suppliers in Nicaragua, ECAMI and TECNOSOL which actually work in promotion, sale and installation of photovoltaic packages to attend the family demand according to the family income.

Local suppliers consider that the role of Grupo Fenix is important to disseminate the technology, but it is very important to keep in mind that solar panels manufactured locally must fulfill a minimum specifications, or will fail very soon, which will affect the community acceptance.

The different projects supported by NGOs and Government have resulted in a drastic increase in installed power of 21 kWp per year.

ANNEX 10. A SURVEY OF THE STATUS OF 91 PV SOLAR HOME SYSTEMS IN BUNGOMA, MURANGA AND OL KALOU, KENYA

SURVEY REPORT

Report Prepared for
ECN Netherlands

March 13, 2000

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1.0 Introduction

EAA was hired to assist ECN to carry out a survey and analysis of reported experiences with the functioning of autonomous PV systems in the field. The study focuses on 3 applications: solar home systems, solar lanterns and solar battery charging stations. EAA has reliable information about solar home systems and lanterns in Kenya and Tanzania.

In the information package provide, Energy Alternatives Africa provide the following information to ECN:

a) Provide reports on the use of solar home systems or solar lanterns in Kenya Tanzania, Uganda and other countries in which EAA is active.

   6 reports were assembled and are contained in the deliverable package.

b) EAA assembled and collated information about 91 PV-systems for which EAA has reliable data based on regular maintenance visits. These include 69 systems financed systems installed under a World Bank ESMAP programme through local banking organisations (K-REP and Cooperative Bank of Kenya) and 22 systems installed by a private contractor using the same maintenance and certification system developed by the programme. This package includes both raw data (i.e. maintenance forms), as well as collated tables describing the performance of the systems, and causes of failure. A summary description of the systems with observations and findings is included below.

2.0 The Systems

All systems were designed by either EAA or Henry Mumiuka to standards laid out by EAA in its ESMAP Implementaion Manual. As well, all 69 ESMAP systems used components from the same set of manufacturers, namely:

- ➢ Solarex modules (32 to 60 Wp x-Si)
- ➢ Neste Advanced Power System modules (12 Wp a-Si)
- ➢ Sollatek (UK) Charge regulators Setting of charge regulator disconnect was 11.9 VDC for the systems in the project.
- ➢ Sollatek (UK) fluorescent lamps 7-11 Watts (all PL-type).
- ➢ Chloride Exide (Kenya) 75-100 Ah battery

The 32 privately-installed systems used various other components including BP charge regulators, 12VDC incandescent lamps, Voltmaster batteries, as well as NAPS and Solarex modules. The maintenance forms do not specify the brands of equipment used on these systems. These systems ranged in size from 12 Wp to 80 Wp, and included one colour TV system and one refrigerator system.

Price paid for systems. In the ESMAP project, households paid three prices for three different system sizes (this cost includes installation):

- ➢ 6 light systems with 100 Ah batteries and 60 Wp modules sold at Kshs 67000.
- ➢ 4 light systems with 100 Ah batteries and 40 Wp modules sold at Kshs 53000
- ➢ 2 light systems with 75 Ah batteries and 24 Wp a-Si modules sold at Kshs 34,000

Prices paid for the private Bungoma systems are contained in the system maintenance forms. (71 Kenya shilling = 1 US$ March 8, 2000).

2.1 Bungoma Systems:

These systems were installed by Henry Mumiuka of Bright Home Solar Systems, a small company based in Kamukuywa Market in Western Kenya. 25 of the Bungoma systems were installed under the ESMAP World Bank activity while the other 32 were installed on a commercial basis. Mr. Mumiuka took up the practice of using the completion, inspection and maintenance forms for his business and allowed EAA access to records he keeps on routine visits.

ESMAP SHS loans were issued by Kenya Rural Enterprise Programme (a finance NGO), and they are handling repayment. Some of the loanees (<50%) are behind sch

2.2 Ol' Kalou Systems

These 20 systems were installed in December 1998 as part of a World Bank ESMAP programme by James Nyaga, a sub-contractor to the project. They were inspected by EAA. Follow-up maintenance work was conducted by Nyaga under contract from EAA. At the time of the last inspection, the systems were about one year old. Maintenance is still on-going.

Ol Kalou Dairy Farmers Savings and Credit Cooperative handled collection of the loans. All loan repayments are up to date.

2.3 Muranga Systems

These 14 systems were installed in February - April 1998 as part of a World Bank ESMAP programme by James Nyaga, a sub-contractor to the project. Systems were inspected by EAA. Follow-up maintenance work was conducted by Nyaga under contract from EAA. At the time of the last inspection, the systems were about two years old. Inspection contracts have come to an end.

Muranga Tea Farmers Savings and Credit Cooperative handled collection of the loans. All loan repayments are up to date. Over half have completed payment in full.

3.0 Condition of Systems

Table 1 below summarises the condition of the systems. In general, the systems were functioning well.

⇒ 77% were functioning normally and had no reported problems
⇒ 23% had at least one problem
⇒ 21% had a failed battery
⇒ 6.6% had more than one problems
⇒ 0% reported module problems

Those faults detected were all due to failed components. Most of the problems were rectifiable, and all faulty lights and regulators were replaced under warranty. Battery warranty is only 1 year, so customers whose battery failed after one year had to purchase another one. Some customers whose batteries had failed delayed purchase of a replacement battery because of the expense.

Problems with batteries may have caused problems with other components (i.e. lights) on some systems.

Table 1: Summary of Problems Found on Systems

Location	System Visited	Systems Inspected	Problems on Inspected	Problems on Non-Inspected	Charge Control problem	Battery problem	Module problem	Lights problem
Bungoma	57	24	10	6	5*	15*	0	9
Ol'Kalou	20	15	4	0	0	3	0	2
Muranga	14	14	1	0	0	1	0	0
Total	91	53	15	6	5	19	0	11

* 8 of the 15 systems did NOT have charge regulators. These were installed commercially and not as part of the ESMAP programme. Only one of the systems without a charge regulator had battery problems.

3.1 Battery

Battery quality control is the major problem with the systems in this project.[7] Almost all batteries were from one manufacturer, Chloride Exide Kenya. All were "Solar Batteries" (modified SLI-type flooded lead acid) of 75 or 100 Ah. Most were over one year old when they failed. Of all failed batteries, only 2 did not have charge regulators (in Muranga, the regulator had been disconnected by the owner). It is likely that batteries failed because of (1) quality control problems in the factory or (2) long periods on the shelf under self-discharge before delivery (this was a big problem in the Bungoma K-REP systems).

The systems without charge regulators were all small systems (12-20 Wp) and were mainly for one light and a B&W TV only. The systems were well-sized for intended loads.

Failed Ol Kalou batteries were less than one year old and were replaced under warranty.

Table 2: Battery Failure Summary

Failure	0-6 mos	7-12 mos	13-18 mos	19 or more mos
Number of Batteries	3*	6*	6	4

* Replaced under warranty

Note that the low voltage disconnect in all of the ESMAP systems was set at 11.9V open circuit for this project.

3.1 Lights

Lights were the second biggest problem in this study. Only one type of manufacturer was used in all systems: the Sollatek PL and Lumina fluorescent luminaires. Of the 11 lights with problems, 9 were from Bungoma ESMAP projects; the fault was likely to be a quality problem in the batch.

Main problem with lights was blackening of the PL tubes. The manufacturer replaced all the tubes as part of the service contract.

3.3 Charge regulators

[7] Note that when the ESMAP project began Chloride Exide/Associated Battery Manufacturers had recently replaced their old battery production line with a new line. There were a number of problems with that production line.

Main cause of failure as diagnosed by the maintenance team was failures in the circuit boards. All were repaired and replaced by the manufacturer.

3.4 Modules

Of the 91 systems, 75 used crystalline modules and 16 used amorphous modules. There were no observed failures of modules.

ANNEX 11. WORKSHOP: THE APPLICATION OF PV IN DEVELOPING COUNTRIES (IN DUTCH)

Verslag van workshop gehouden op 17 mei 2000, Novem, Utrecht

Project "Monitoring en evaluatie van Solar Home Systemen":

Presentaties door projectuitvoerders
Frans Nieuwenhout (ECN); Vincent van Dijk(UU); Danielle Hirsch (Fusion 21); Annemarije van Dijk (ECN)

A. Discussiestellingen

Sheet 1: CONCLUSIES EN AANBEVELINGEN VOOR VERVOLG

Conclusies:

- Weinig productieve toepassingen, wel besparing energiekosten, vooral toename welzijn
- Te weinig kennis gebruik en functioneren in praktijk van SHS
- Beschikbare kennis is niet makkelijk toegankelijk

Aanbevelingen voor vervolgactiviteiten:

- Uitvoeren van monitoring en evaluatie van verschillende projecten
- Onderhouden en uitbreiden van een database met gegevens over projecten en markten

Discussie naar aanleiding van sheet 1:
SHS worden in West Afrika wel vaak gebruikt voor het genereren van inkomsten (indirect dwz door het gebruikmaken van licht).

Deelnemers prefereren een snelle beschikbaarheid van de database, met duidelijke kanttekeningen bij de sterke en zwakke elementen ervan.

Deelnemers geven aan dat ze interesse in monitoring en *met name* evaluatie hebben van bepaalde projecten en markten.

Conclusie naar aanleiding van sheet 1:
beide aanbevelingen worden door meerderheid ondersteund.

Sheet 2: CONCLUSIES EN AANBEVELINGEN VOOR VERVOLG

Conclusie:

- Kwaliteit elektronica van laadregelaars en lampen vaak laag

Aanbevelingen voor vervolgactiviteiten:

- Ondersteun verbeterde ontwerpen en implementatie van:
- TL en CFL lampen welke aan minimum eisen voldoen
- Intelligente laadregelaars met b.v. Ah teller;
- Verbeterde interface naar gebruiker

- Ondersteun technologie overdracht lokale fabricage BOS-componenten naar ontwikkelingslanden door:
- Training in verbeteren bestaande ontwerpen
- Ondersteuning bij tot stand komen joint ventures en licentieovereenkomsten voor lokale productie

Discussie naar aanleiding van sheet 2:
De definitie van ‘kwaliteit’ is niet duidelijk. Kwaliteit wordt door ons gedefinieerd als de mate waarin het product of de dienst voldoet aan de verwachtingen van de gebruiker. Het ontwikkelen van nieuwe –kwalitatief goede- producten is niet nodig; het huidige (potentiële) aanbod is goed en gediversifieerd genoeg, alleen ontbreekt het de eindgebruiker aan voldoende informatie om de juiste keuze te maken. Om de keuzevrijheid zo groot mogelijk te maken (houden) en ervoor te zorgen dat een eindgebruiker de gewenste prijs-kwaliteit verhouding kiest, zijn betrouwbare productinformatie en transparantie van de markt van veel groter belang.

Transparantie van de markt is belangrijk. Een goede informatievoorziening richting consument is hiervoor een voorwaarde. Certificering of het gebruiken van keurmerken/ richtlijnen kan een bijdrage leveren.

Het is van belang sterke lokale structuren te ondersteunen, om te voorkomen dat projecten of markten stuklopen op bijv. het gebrek aan componenten.

Voorstel naar aanleiding van sheet 2:
- rol van eindgebruikers versterken door empowerment, bijvoorbeeld door een soort consumentenbond op te richten.

Conclusie naar aanleiding van sheet 2
Dit laatste voorstel wordt aangenomen, de aanbevelingen op de sheets worden afgewezen.

Sheet 3: CONCLUSIES EN AANBEVELINGEN VOOR VERVOLG (III)

Conclusies:

- Het succes van project hangt af van beschikbaarheid personen

- Er zijn weinig ondernemers die zich op commerciële dienstverlening storten

Aanbeveling voor vervolgactiviteiten:

Ontwikkel een flexibel instrument ter ondersteuning van startende ondernemers op PV gebied:
- Training in bedrijfsvoering
- Ondersteuning bij het samenstellen producten- en diensten pakket
- Financiële ondersteuning voor investeringen in voorraden en opzetten van service stations

Discussie naar aanleiding van sheet 3:
De vraag wordt gesteld wie de training moet geven. Antwoord: multilaterale, bilaterale en commercieel opererende organisaties.

Opgemerkt wordt dat in de overgrote meerderheid van de landen de link tussen overheid en commerciële MKB ontbreekt. Daar moet wat aan veranderen.

Het is belangrijk dat aangesloten wordt bij bestaande initiatieven en distributiekanalen; het is niet gewenst een nieuwe groep ondernemers te creëren.

Conclusie naar aanleiding van sheet 3:
De aanbeveling worden aangenomen, met bovenstaande kanttekeningen.

B. Vragenrondje

Nol Verster
- Er moet beter nagedacht worden over de afstemming tussen vraag en aanbod. Op dit moment wordt veel te veel gehandeld vanuit de aanbodkant.
- kostprijs die uit de database komt (presentatie financieringsmechanismen) is te hoog

Antje van Driel
- wat zijn de ervaringen met duurzaamheid van projecten (na enkele jaren?)
- interesse in meer gegevens t.a.v. de productiviteitseffecten van SHS

Ad Zomers
- mededeling: FAO verslag beschikbaar- de PV markt is rijp om' beyond the lightbulb' te reiken

Jaap Jansen
- het vergroten van toegang tot informatie (bijv via TV of radio) kan indirect ook bijdragen aan een toename van productiviteit, en SHS kan deze informatie aanzienlijk toegankelijker maken

Ronald Siemons

- doelstellingen van projecten verschillen dus automatisch de resultaten ook; discussies over ‘succes’ activiteiten wordt daardoor vaak vertroebeld

Frank van der Vleuten:
- informatie moet toegankelijk worden gemaakt- er zijn nog geen conclusies mogelijk over welk distributiemodel het meest geschikt is. Ook is nog weinig bekend over hoe de gebruiker met een SHS omgaat

Leendert Verhoef
- wat zijn de ervaringen van het effect op de markt van het falen/ niet functioneren van een merk/ type product
- toegang tot informatie is gewenst: liever onzekere informatie dan geen informatie
- wat is bekend over de snelheden van marktintroductie?
- wat is bekend over de prijzen voor de consument?

Jeroen van der Linden
- wat is het effect op energiebestedingen op termijn (langer en meer energieverbruik tegenover besparingen)
- effecten op educatie?
- effecten op migratie?

Menno Kardolus
- omdat subsidies tijdelijk zijn is het belangrijk dat lokale structuren /markten worden ontwikkeld
- wat gebeurt er met accu's? (milieu)

Patrick van der Rijt
- effectiviteit van rijkere/ armere doelgroepen - marktontwikkeling, technisch functioneren;
- is er sprake van een ‘trickle down’ effect?

Jan Nijland
- kunnen armen in ontwikkelingslanden toch bereikt worden met PV bijv de PV lantaarn?
- er is ervaring dat PV systemen doorstromen van steden en rijke landen naar de rurale armere bevolking

Gwen van Roekel
- de kennis en ervaring van alle aanwezigen kan gebruikt worden voor het formuleren van onderzoeksvragen voor veldonderzoek ('reference points' voor grote programma's zoals PV GAP)

Chris Westra
- PV voor telecommunicatie is zich zichtbaar snel aan het verspreiden over de rurale gebieden van Zuidelijk Afrika
- ondernemers in de telecommunicatie hebben weinig belangstelling om te investeren duurzame SHS disseminatie

Tim Mulder
- misschien is meer onderzoek nodig, er kan ook gebruik gemaakt worden van de eigen ervaringen van de aanwezigen

Anne Brunia
- Wat is eigenlijk de rol van andere OECD-landen (andere donoren) op de PV-markt in ontwikkelingslanden?

Winfried Rijssenbeek

- onderzoek naar de sociale aspecten van PV gebruik is nodig - wat zijn succesvolle marketingstrategieën
- PV is nog geen echte markt

Edwin Wiggelinkhuizen

- Wat zijn de verwachtingen van de eindgebruiker met betrekking tot kwaliteit?

Harry Oppenoorth

- De resultaten vallen tegen; er moet meer duidelijkheid komen over de vraag vanuit de eindgebruiker en de manier waarop daar effectief aan tegemoet gekomen kan worden

Simon Kuyvenhoven

- verdiepen van de inhoud van de database met behulp van interviews

Wieland Koornstra

- weg met productsubsidies, steun lokale infrastructuur! (risico dekken)
- wat zijn de verschillen in prestatie tussen grote en kleine projecten?
- wat zijn de verschillen in nazorg tussen commerciële markt en projecten?
- waartegen concurreert PV (betrouwbaarheid van het net, schade aan apparatuur)
- er wordt te veel verwacht van de gebruikers

Jos van de Ven

- aandacht voor financiële instituties is belangrijk
- stelling: goede systemen zijn simpel te installeren, vergen weinig onderhoud, de gebruiker mag niet kunnen interveniëren
- marketing, logistiek, hoe wordt geld opgehaald?

Bob Schulte

- het onderzoek is gebaseerd op objectief onderzoek- de eigen conclusies van de aanwezigen moeten niet verwerkt worden IN het rapport

Jan Lam

- invloed van distributiesysteem op de markt (kan commerciële markt bestaan naast projecten?)
- meer aandacht voor marketing vanuit de klant (Bij PV te veel vanuit de techniek)

Quirin Sluijs

- PV is een onvolwassen markt- consumentinformatie is belangrijk
- Ecofys werkt aan informatieverstrekking via internet

Rob Hommerson

- meer technische feedback vanuit het veld
- wat is de kostprijs van componenten en systemen en wat zijn de verbanden met de levensduur?

Wim van Nes

- conceptverslag wordt eind mei rondgestuurd naar de deelnemers van de workshop, die dan 2 weken de gelegenheid krijgen commentaar te leveren

De medewerkers van het project bedanken alle aanwezigen voor de bijdrage aan deze geslaagde middag, en Novem voor de organisatie.

Afspraken:

- Deelnemers sturen (aanvullende) vragen per email naar ECN (nieuwenhout@ecn.nl of vandijk@ecn.nl). Deze zullen –indien mogelijk- worden verwerkt in het verslag van de bijeenkomst.
- Projectteam stuurt alle deelnemers een elektronische versie van het verslag.
- Projectteam stuurt alle deelnemers de concept eindtekst van het projectdocument, uiterlijk 31/5/00.
- Deelnemers die opmerkingen/ aanvullingen op de tekst hebben kunnen binnen twee weken reageren op de concept-eindtekst.
- Reacties deelnemers worden verwerkt in document door projectteam.
- Einddocument per 30/6/00 beschikbaar voor alle geïnteresseerden.